Environment Canada Environnement Canada

National Hydrology Research Institute

NHRI PAPER NO. 26
IWD SCIENTIFIC SERIES NO. 145

Ground Water Supply – Fraser Lowland, British Columbia

E.C. Halstead

NHRI

INLAND WATERS DIRECTORATE
NATIONAL HYDROLOGY RESEARCH INSTITUTE
NATIONAL HYDROLOGY RESEARCH CENTRE
SASKATOON, SASKATCHEWAN, 1988

(Disponible en français sur demande)

Published by authority of
the Minister of the Environment

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Cat. No. En36-502/145E

ISBN 0-662-15086-4

Contents

	Page
ABSTRACT	vii
RÉSUMÉ	vii
ACKNOWLEDGMENTS	viii
INTRODUCTION	1
Purpose and scope of investigation	1
Location and extent of area	1
Previous investigations	1
GEOGRAPHY	3
Topography and surface drainage	3
Climate	4
Economics	4
GEOLOGY	6
Bedrock geology	6
Surficial geology	7
HYDROGEOLOGY	8
Hydrostratigraphic units	8
Hydrostratigraphic unit A	8
Hydrostratigraphic unit B	8
Hydrostratigraphic unit C	8
Hydrostratigraphic unit D	9
Hydrostratigraphic unit E	10
Hydrostratigraphic unit F	11
Distribution of aquifers	11
Township 1	11
Township 2	12
Township 7	15
Township 8	15
Township 9	17
Township 10	21
Township 11	21
Township 12	21
Township 13	25
Township 14	26
Township 15	26
Township 16	29
Township 17	29
Township 18	33
Township 19	33
Township 22	33
Township 23	34
Ryder Lake–Promontory Heights	43
Kent District Municipality	43

Contents (Cont.)

	Page
HYDROCHEMISTRY	50
Evaluation of water quality analyses	50
Selected physical and chemical parameters	50
Alkalinity	50
Calcium and magnesium	50
Chloride	52
Colour	52
Fluoride	52
Hardness	52
Iron and manganese	52
Nitrates	53
Phosphate	53
Hydrogen ion (pH)	53
Sodium and potassium	55
Specific conductance and total dissolved solids	55
Sulphate	55
Taste and odour	55
Ground-water temperature	55
Pollution	55
GROUND-WATER USE AND MANAGEMENT	56
CONCLUSION	58
REFERENCES	60
APPENDIX A. Acceptable water quality levels	61
APPENDIX B. Water quality analysis report	65
APPENDIX C. Yields of significant wells	69

Tables

1. Stratigraphic test holes drilled in the Fraser Lowland	3
2. Late Quaternary lithostratigraphic units and related hydrostratigraphic units in the Fraser Lowland	7
3. Water consumption in the Fraser Lowland	59

Illustrations

		Page
Figure 1.	Location map, Fraser Lowland, British Columbia	2
Figure 2.	Hydrographs, water table elevations in observation well, Surrey District Municipality	5
Figure 3.	Distribution of Quaternary deposits in the Fraser Lowland	6
Figure 4.	Weathered stony clays, Bertrand Creek	9
Figure 5.	Ground-water discharge along the toe of a delta, 4000 block, 192 Street, Surrey District Municipality	10
Figure 6.	Well location map and hydrogeological fence diagram, Township 1, Surrey District Municipality	in pocket
Figure 7.	Flowing artesian well, 16510-32 Ave. following completion in August 1969	11
Figure 8.	Well locations, Township 2, Surrey District Municipality	13
Figure 9.	Well location map and hydrogeological fence diagram, Township 7, Surrey and Langley district municipalities	in pocket
Figure 10.	Hydrographs, observation well, Section 27, Township 7, Surrey District Municipality	16
Figure 11.	Well location map and hydrogeological fence diagram, Townships 8 and 9, Surrey and Langley district municipalities	in pocket
Figure 12.	Flowing artesian well, 172 Street, Section 30, Township 8, Surrey District Municipality	17
Figure 13.	Well locations, Township 9, Surrey-Pitt Meadows District Municipality	19
Figure 14.	Well location map and hydrogeological fence diagram, Township 10, Langley District Municipality	in pocket
Figure 15.	Well location map and hydrogeological fence diagram, Townships 11 and 12, Langley District Municipality	in pocket
Figure 16.	Hydrographs, observation well, Section 4, Township 11, Langley District Municipality	22
Figure 17.	Well locations, Township 12, Langley and Maple Ridge district municipalities	23
Figure 18.	Well location map and hydrogeological fence diagram, Township 13, Langley and Matsqui district municipalities	in pocket
Figure 19.	Ice-contact sand and gravel pit with an exposed water table	25
Figure 20.	Well location map and hydrogeological fence diagram, Township 14, Langley and Matsqui district municipalities	in pocket
Figure 21.	Well locations, Townships 14 and 15, north of Fraser River, Maple Ridge and Mission district municipalities	27
Figure 22.	Well location map and hydrogeological fence diagram, Township 16, Matsqui and Abbotsford district municipalities	in pocket
Figure 23.	Water table exposed in gravel pits, Section 7, Township 16, Matsqui District Municipality	29
Figure 24.	Hydrographs, Clearbrook Municipal Well Fields	30
Figure 25.	Well locations, Township 17, Matsqui and Mission district municipalities	31
Figure 26.	Well locations, Township 18, Mission District Municipality	35
Figure 27.	Well locations, Township 19, Abbotsford District Municipality	37
Figure 28.	Well locations, Township 22, Abbotsford and Chilliwack district municipalities	39
Figure 29.	Well locations, Township 23, Chilliwack District Municipality	41
Figure 30.	Well locations, Ryder Lake-Promontory Heights District, Chilliwack District Municipality	45

Illustrations (Cont.)

		Page
Figure 31.	Well and piezometer locations, Harrison Hot Springs-Agassiz District, Kent District Municipality	47
Figure 32.	Water table profiles, Agassiz area during flood stages on Fraser River	49
Figure 33.	Water quality, Fraser Lowland aquifers	51
Figure 34.	Distribution of chlorides in regional flow systems in the Fraser Lowland	in pocket
Figure 35.	Nitrate levels	54
Figure 36.	Mushroom manure stockpiled in abandoned gravel pit in which water table is at or near the surface of the pit	56
Figure 37.	Aggregate quarry, well site No. 34, Table C-1	57
Figure 38.	Drilling wells by jetting, 1955	71
Figure 39.	Well screen	71
Figure 40.	Set-up for a pump test	72
Figure 41.	Typical cross section of a well being pumped	72
Figure 42.	Map showing locations of production wells in the Fraser Lowland, British Columbia	in pocket

Abstract

This report describes, on a township basis, the ground-water resources of the Fraser Lowland in British Columbia. The surficial deposits that provide the physical framework controlling ground-water flow and occurrence are divided into five hydrostratigraphic units. The complex relationship of these units, classified on the basis of grain size and depositional environment, is illustrated on fence diagrams. Hydrochemical parameters are discussed as they apply to the various components of the ground-water flow system in the Lowland. Ground-water chemistry is characterized by a geochemical evolution of the water flowing from the recharge areas in the uplands to the discharge areas of the local and regional flow systems. In 1981, ground-water supplies accounted for 44% of the total water requirements in the area.

Résumé

Le rapport fournit une description, par canton, des ressources en eau souterraine des basses-terres du Fraser, en Colombie-Britannique. Les formations de surface, qui constituent le cadre physique de l'emplacement et de l'écoulement des eaux souterraines, sont divisées en cinq unités hydrostratigraphiques. Les diagrammes des clôtures montrent le rapport complexe entre ces unités, classées selon la dimension granulaire et le milieu de sédimentation. Les paramètres hydrochimiques sont étudiés par rapport aux divers éléments du bassin d'écoulement des eaux souterraines dans les basses-terres. La chimie de ces eaux est caractérisée par une évolution géochimique des eaux qui s'écoulent des zones d'alimentation dans les hauteurs vers les zones d'émergence des bassins d'écoulement locaux et régionaux. En 1981, 44 % de l'eau utilisée dans la région provenait des eaux souterraines.

Acknowledgments

The co-operation of a number of hydrogeological consultants is acknowledged and credit given for their contributions in Table C-1 of Appendix C. H.M. Liebscher assisted with the compilations and in particular the original drafts of the fence diagrams. Aqua-Flo Testing and Equipment Ltd. and the following drilling contractors supplied records and logs:

A. & H. Construction Co. Ltd.
Columbia Water Wells Ltd.
Halvorsen Drilling Ltd.
H. & R. Well Drilling
Jay-Dee Drilling Services
Langley Water Wells
Linder's Well Drilling
Nor-West Drilling Ltd.
Pacific Water Wells (1969) Ltd.
Rural Well Drillers Ltd.
Totem Drilling & Pumps
Valley Water Services Ltd.
Walsh Well Drilling
Western Water Wells Ltd.

Ground Water Supply – Fraser Lowland, British Columbia

E.C. Halstead

INTRODUCTION

Purpose and Scope of Investigation

Hydrogeological reports provide basic information on the occurrence, availability and quality of ground water. Reports of this nature, covering the district municipalities of Surrey, Langley, Matsqui, Sumas and Chilliwack,[1] were published by the Geological Survey of Canada in the 1950s. The demand for additional water supplies to satisfy the increasing requirements for domestic, industrial and irrigation use has resulted in the need for a better understanding of the distribution of ground-water resources in the Fraser Lowland. To provide this information, the compilation of about 20 years of investigations is reported herein, together with maps and fence diagrams representing those townships in which ground-water developments are most critical.

Although the area known as the Fraser Lowland could be divided physiographically into hydrogeologic areas, the decision was made to report the resource data on a township basis. Accompanying this report are maps of townships showing well locations and, where applicable, fence diagrams of the geologic framework through which ground water is recharged, stored, naturally discharged and recovered by well installations.

Location and Extent of Area

The Fraser Lowland includes the southwest corner of the Pacific Coast mainland of Canada and the adjoining northwest corner of the continental United States. The part of the Fraser Lowland included in this report (Fig. 1) covers the area south of the Fraser River that includes portions or all of Surrey, Langley, Matsqui, Abbotsford and Chilliwack district municipalities. As well, that area north of the Fraser River, where ground water serves the communities of Maple Ridge, Mission and Kent district municipalities, is included.

Previous Investigations

The importance of ground water in the Fraser Lowland was realized as early as 1914. During a six-month period of that year, a well inventory was carried out for Vancouver City, the municipalities of North, South and West Vancouver, Point Grey, Burnaby, Maple Ridge, Richmond and the districts of Delta, Surrey and Langley, in all some 800 km^2. The results of this investigation are included in the annual report ending December 31, 1915, published by the Water Rights Branch, Department of Lands, British Columbia.

The investigation found 165 free-flowing wells discharging an estimated 2.24×10^6 m^3/year. Most of the flowing wells delivered the water 1 to 1.8 m above ground level and in some cases as much as 3 to 8 m. The report pointed out that"...101 wells in Cloverdale and Langley districts were discharging 450,000 gallons a day while requirements for the users amounted to approximately 50,000 gallons suggesting a daily waste of 400,000 gallons."

The records indicate that the first wells were drilled in 1908. Two wells, one for Davis and one for Mufford, at Milner, are the oldest recorded and both wells are still in existence. The Davis well was drilled 215 ft (65.5 m) with a 3-in. (76 mm) diameter to yield by free flow about 75 gal/min (5.6 L/s) at temperatures of 50°F (10°C). The Mufford well was drilled 214 ft (65.2 m) with a 3-in. (76 mm) diameter to yield 10 gal/min (0.75 L/s) at temperatures of 50°F (10°C).

The 1914 survey shows that the deepest well was drilled to 800 ft (244 m) at Fort Langley, at the junction of Glover Road and Wilson Townline on the east side, approximately where the present Royal Bank is located. The water was salty and the well was abandoned.

[1] Chilliwack District Municipality used to be spelled Chilliwhack.

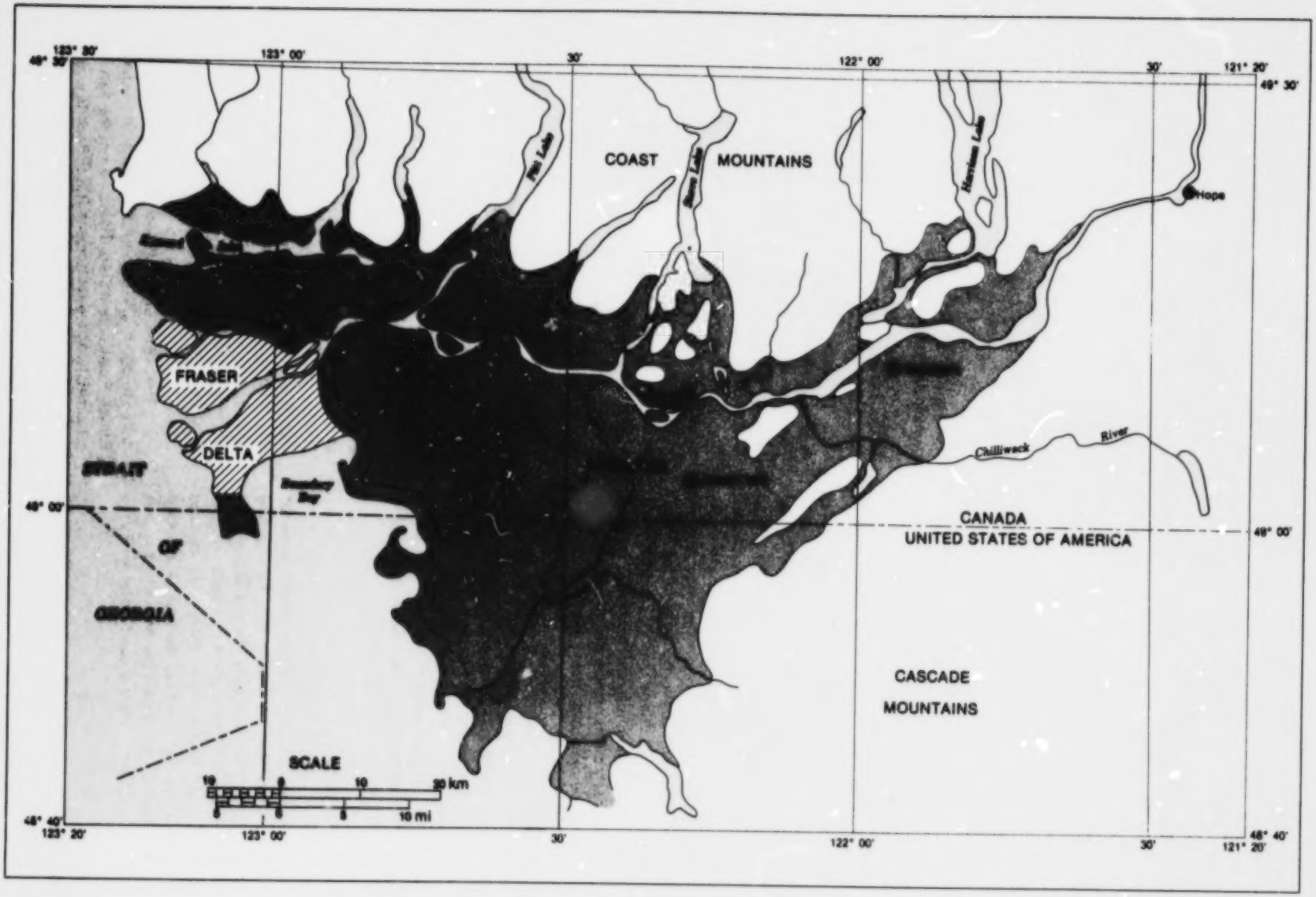


Figure 1. Location map, Fraser Lowland, British Columbia.

Water levels in the Milner area rose to the greatest height above ground level. A well drilled at Milner School in May 1912 was 368 ft (112 m) deep and yielded 80 gal/min (6 L/s) flowing through a 2-in. (50.8 mm) pipe 25 ft (7.6 m) above ground level. In May 1913, a well was drilled 557 ft (170 m) encountering salty water that rose 30 ft (9 m) above ground level and discharged at a rate of 20 gal/min (1.5 L/s). The well was drilled in the vicinity of the present 21000-block, Medd Road.

Because a geological survey was not conducted in conjunction with the well inventory and well logs were not recorded, information on the position and extent of the local aquifers was not available. In 1950, the Geological Survey of Canada initiated a well inventory and geological mapping program to define the ground-water potential of the surficial deposits in the Fraser Lowland. The first water supply paper, the Ground Water Resources of Surrey Municipality, was published in 1953 (Armstrong and Brown, 1953). Subsequently, ground-water investigations were carried out and reports written to cover the district municipalities of Langley, Matsqui, Sumas and Chilliwack (Halstead, 1957, 1959, 1960).

Prior to the ground-water investigations begun in 1950, all wells were drilled as open holes. The first screened well was installed at Morris Nursery on 128th Street, Whiterock, by Surrey Well Drillers in 1951. The first irrigation well was drilled and developed on the Frank Gaspar farm, Townline Road, south of Abbotsford in 1954 by G. & G. Well Drilling Company.

At present, well-drilling contractors operating in the Fraser Lowland submit their well records to the Ground Water Section, Water Management Branch, Ministry of Environment, Province of British Columbia. An estimated 8000 records are on file, and these provided the basic data for the preparation of fence diagrams that accompany this report. These data were supplemented by six test holes drilled for stratigraphic purposes to provide more accurate correlation of the well records and logs (Table 1).

GEOGRAPHY

Topography and Surface Drainage

The southwest corner of the Pacific Coast mainland of Canada and the adjoining northwest corner of the continental United States are commonly referred to as the Fraser Lowland (Fig. 1). This triangular area extends from Hope westward to the Strait of Georgia, approximately 105 km. It has relatively low relief and is bounded on the north by the Coast Mountains, on the southeast by the Cascade and Chuckanut mountains and on the west by the Strait of Georgia. In Canada, the Lowland covers approximately 2600 km^2.

The Fraser River flows through the Fraser Lowland in a late glacial and postglacial valley up to 5 km wide and 225 m deep. This river ends in a growing delta, 31 km long and 24 km wide. North and south of the Fraser River, the Fraser Lowland consists mainly of gently rolling and flat-topped uplands separated by wide, flat-bottomed valleys. Most of the upland areas consist of unconsolidated deposits and do not exceed 175 m in elevation. The uplands range in area from 3 to 400 km^2. Their geology varies greatly, but all were formed by glacial and marine processes.

Table 1. Stratigraphic Test Holes Drilled in the Fraser Lowland

Year	Depth (m)	Section	Township	Method
1963	259.4	NE 1/4 Sec. 30	13	Cable-tool, bailer samples*
1966	301.5	SW 1/4 Sec. 5	8	Cable-tool, bailer samples†
1969	242.3	SW 1/4 Sec. 27	7	Cable-tool, bailer samples†
1970	240.8	NE 1/4 Sec. 11	10	Rotary, electrologged
1970	128.0	NW 1/4 Sec. 18	16	Rotary, electrologged
1970	182.9	SW 1/4 Sec. 5	12	Rotary, electrologged

* Aldergrove Test Hole, Fraser Valley, B.C., GSC Paper 64-51.
† Halstead (1978).

In addition to the valley of the Fraser River, two other major flat-bottomed valleys intersect the upland areas of the Fraser Lowland. They are the Nicomekl and Sumas valleys, both of which were arms of the sea during the period 13 000 to 11 000 years before present (B.P.) (Armstrong, 1981). The Nicomekl Valley is more than 30 km long and 5 km wide and stretches from Boundary Bay northeast to the Fraser River. The Sumas Valley also averages 5 km in width and, in Canada, extends northeast 25 km from the United States border to the Fraser River.

Drainage of the Lowland discharges into the Strait of Georgia via the Fraser River, which flows from east to west. A number of tributary rivers and creeks originate in the adjacent Coast and Cascade ranges. Drainage into the Fraser River on its north side is through Silverdale, Whonock and Kanaka creeks and on the south side through Sumas, Salmon and Nathan creeks. The Nicomekl-Serpentine system and tributaries, as well as the Campbell River, discharge into the Strait of Georgia at Semiahmoo Bay, but Fishtrap and Bertrand creeks drain south across the International Border and into the Nooksack drainage system in Washington State. These creeks all receive groundwater discharge to maintain their flow during the drier summer months.

Climate

The Fraser Lowland can generally be characterized as having warm, rainy winters and relatively cool dry summers. During winter, a fairly steady succession of low pressure systems moving eastward from the Pacific Ocean produces cloudy, rainy conditions, whereas the summers have frequent long periods of sunny weather as high pressure cells extend over the coast. Temperatures are warm and rainfall is low. Soil moisture deficiencies frequently develop, and irrigation is required on some soils to maintain good agricultural production.

Since precipitation is the source of all ground water, precipitation range and pattern are significant. Records from a number of gauging stations, some in operation for more than 50 years, indicate that of the total annual precipitation, approximately 75% falls during the period October to March. These data also indicate a strong increase in precipitation occurring from south to north and from west to east due to orographic effects of the nearby Coast and Cascade mountains. The following table shows the average annual precipitation for the ten-year period 1969 to 1978 at a number of stations (Climate of British Columbia).

Station (elevation in parentheses m a.s.l.)	Precipitation (mm)
Abbotsford Airport (58)	1497
Agassiz Research Station (15)	1626
CFB Aldergrove (76)	1620
Chilliwack (6)	1839
Cultus Lake (46)	1433
Langley Lochiel (105)	1359
Mission (56)	1627
Rosedale (11)	1459
Surrey Municipal Hall (76)	1242
Surrey Newton (73)	1386
Surrey Sunnyside (101)	1182
Whalley Forest Nursery (84)	1497
White Rock STP (15)	1053

During the period October to March, when precipitation is heaviest, evaporation and evapotranspiration are minimal; hence most of the precipitation falling on the land surface is available to percolate into the soils and subsoils eventually to recharge or replenish the aquifers. The effect of the recharge is indicated in Figure 2, which shows a hydrograph of the static level in an observation well during the period of heavy rainfall November 10, 1981, to January 31, 1982.

Variations in total annual precipitation are also significant. For example, at Abbotsford Airport, precipitation for the year 1980 was 1756 mm but for the year 1973, only 1210 mm. During the periods when annual precipitation is below normal, as in 1973, it is not uncommon for recharge to the ground water to be insufficient to sustain yields in the shallower dug wells. During such times, some wells have to be deepened to intercept the declining water tables. For most years, precipitation is more than adequate to recharge the aquifers.

Economics

The central part of the Fraser Lowland is mainly agricultural, containing 13.5% of all farms in British Columbia. Dairying accounts for 285 commercial farms; egg and poultry production supplies 80% of the British Columbia market. Within a 25- to 30-km radius of Abbotsford, 80% to 85% of the total Canadian raspberry crop is harvested. Favourable farming conditions permit the growing of vegetables, flowers, bulbs, mushrooms and the raising of hogs, sheep and fur-bearing animals. Greenhouse crops are important in some areas.

Agriculture remains the backbone of the local economy, but urban and industrial pressures are strong in this traditionally rural area. The bulk of the industrial activity is related to agriculture; brick is manufactured from clay deposits on Sumas Mountain and extensive gravel deposits are excavated for sand and gravel.

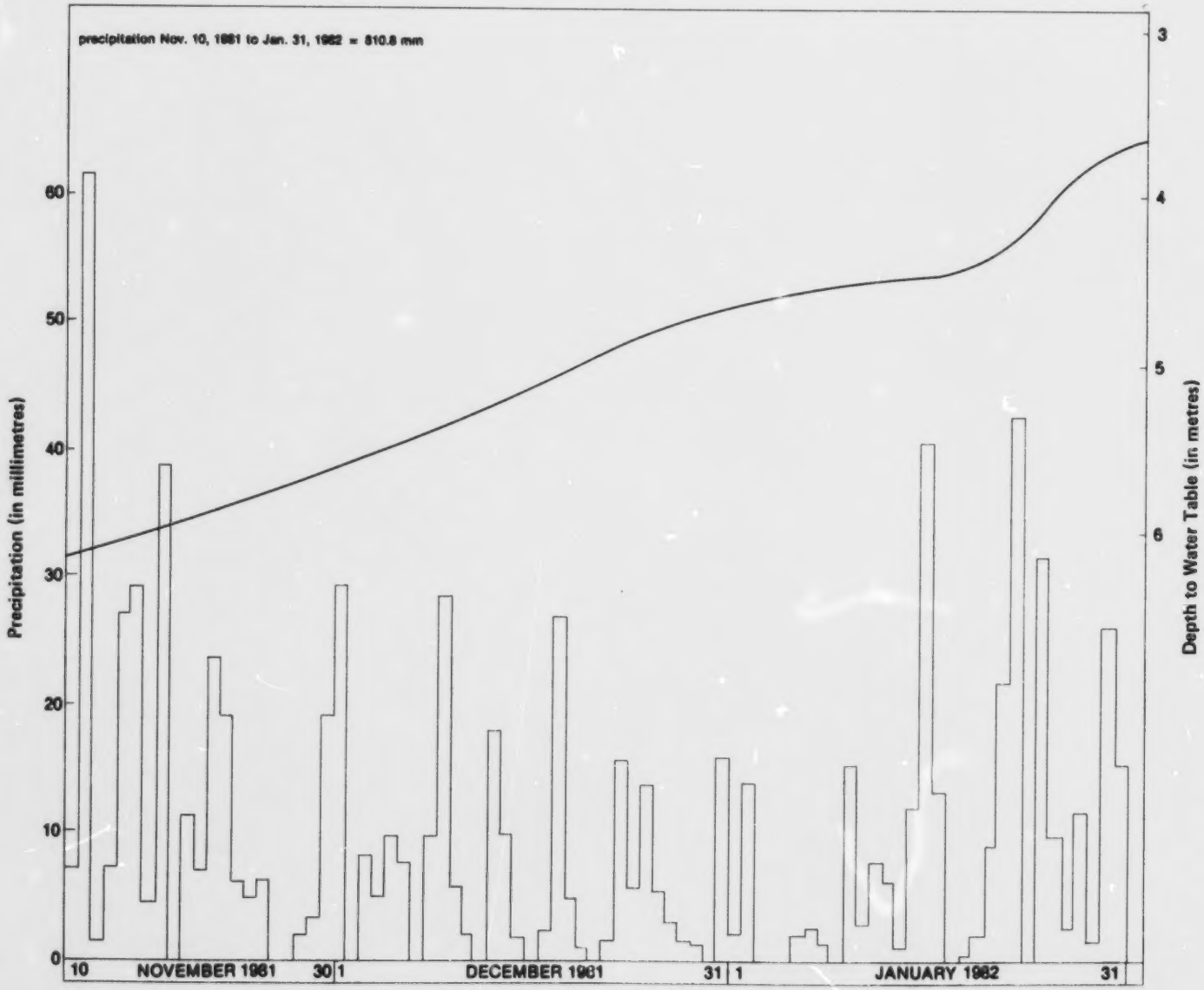


Figure 2. Hydrographs, water table elevations in observation well, Surrey District Municipality.

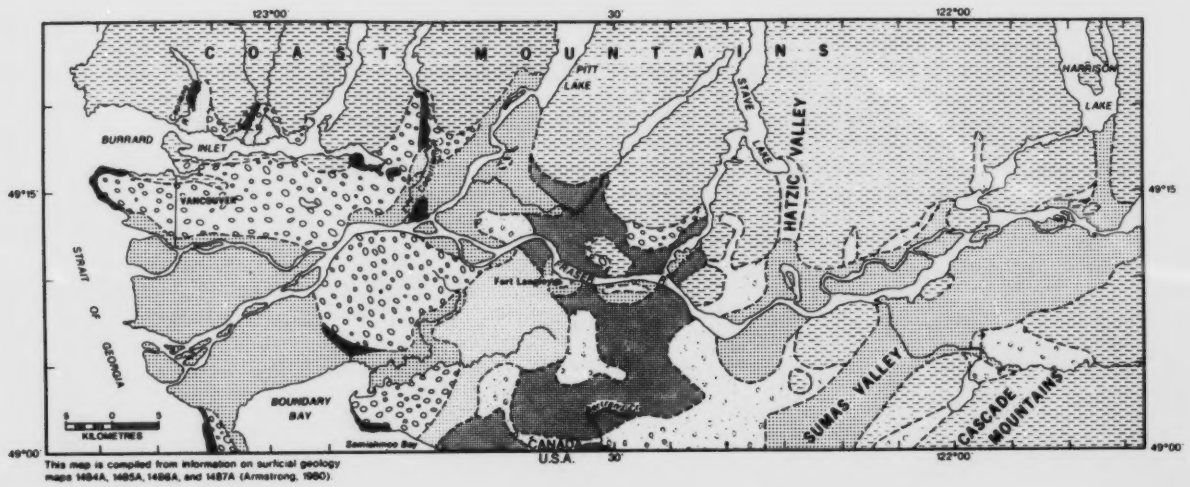
GEOLOGY

The geologic setting of the Fraser Lowland is that of a major structural trough which has subsided repeatedly since late Cretaceous time (Mathews, 1972). This trough gradually filled, first with sediment brought by rivers from denudation of the adjacent mountains, and eventually with sediments of marine, fluvial and glacial origin, related to the Quaternary period, the glacioclimatic episode of the last 1.8 million years. These surficial deposits are the common source of ground water, but bedrock may also serve as an aquifer for dependable supplies.

Bedrock Geology

The Coast and Cascade mountains that form the boundaries of the Fraser Lowland are major mountain systems that have existed since Upper Cretaceous time, about 65 to 80 million years ago (Roddick, 1965). The geological record for this area indicates that about 300 million years ago, prior to the mountain-building episode, volcanic and sedimentary strata were subjected to the intrusion of magmatic material which, during its slow ascent from great depths to the higher levels of the earth's crust, cooled and crystallized, forming the minerals quartz, feldspar, hornblende and biotite. With this mineral assemblage, the slow cooling resulted in coarse-textured crystalline igneous rocks, referred to as granitic rocks (Eisbacher, 1973). These granitic rock types, namely granite, granodiorite and quartz diorites, make up 70% to 90% of the Coast Mountains and 30% to 40% of the Cascade Mountains (Roddick, 1965) and provide many local aquifers with limited supplies.

Following the mountain building episode, the uplifted land masses were subjected to weathering. Streams and rivers carried the weathered materials, namely clay, silt, sand, gravel and organic material, to the adjacent seas. These materials are now exposed as shales, siltstones, sandstones and conglomerates along the flanks of the mountain and are found in drill holes that reach depths of more than 300 m in the Fraser Lowland. During this period and continuing to the present, intermittent volcanism has continued, and basaltic rocks are found interbedded with and intersecting the sedimentary rocks. Examples of such rocks are exposed in the Whonock area north of the Fraser River. These basaltic rocks constitute favourable water-bearing units.



POSTGLACIAL
- SALISH AND FRASER RIVER SEDIMENTS

LATE WISCONSIN
- SUMAS DRIFT
- FORT LANGLEY FORMATION
- CAPILANO SEDIMENTS
- VASHON DRIFT In most of the area west of Fort Langley VASHON DRIFT is overlain by a thin veneer of CAPILANO SEDIMENTS

MIDDLE WISCONSIN AND EARLIER
- QUADRA SAND, COQUITLAM DRIFT, COWICHAN HEAD FORMATION, SEMIAHMOO DRIFT, HIGHBURY SEDIMENTS, AND WESTLYNN DRIFT

TERTIARY AND OLDER
- Rock at or within 10 m of surface mantled with surficial deposits

Figure 3. Distribution of Quaternary deposits in the Fraser Lowland.

Surficial Geology

The Fraser Lowland is underlain by Quaternary deposits up to 300 m thick, with bedrock hills projecting through the Quaternary cover in only a few localities (Armstrong, 1977). These surficial deposits provide the physical framework which controls the configuration and character of the ground-water flow systems.

Surface distribution of the Quaternary deposits in the Fraser Lowland is shown in Figure 3, and their stratigraphic record indicates that the Lowland was repeatedly invaded by glaciers from the adjacent high mountains during the Pleistocene Epoch. Thick, complex drift sequences deposited in association with these glaciers were eroded by overriding ice and by fluvial, marine and mass-wasting processes operative during nonglacial intervals. As a result of these processes, the Quaternary deposits in the Fraser Lowland consist of several drift packages separated by unconformities and by nonglacial deposits (Clague and Luternauer, 1982).

Each major glaciation was accompanied by isostatic adjustments related to glacier build-up and decay. Combined with eustatic changes in sea level, these glacio-isostatic adjustments produced vertical fluctuations in shoreline positions of up to 200 m in the Fraser Lowland (Mathews *et al.*, 1970). As a consequence, low-lying land areas were repeatedly inundated by the sea during Pleistocene time, and marine, glaciomarine and deltaic sediments were deposited in complex associations with glacial, glaciofluvial and ice-contact materials (Clague and Luternauer, 1982).

The early Quaternary history of the Fraser Lowland is little known, except for records of deep drill holes which indicate thick marine sequences underlying large parts of the Lowland. The later Quaternary stratigraphic units, revealed in surface exposures, are divided into mappable units shown in Table 2 (Armstrong, 1981). These units are related to glacioclimatic events that were cyclic; therefore similar sedimentary environments existed during deposition of certain units which, for the purpose of this report, can be grouped into hydrostratigraphic units (Table

Table 2. Late Quaternary Lithostratigraphic Units and Related Hydrostratigraphic Units in the Fraser Lowland

Lithostratigraphic units*	Hydrostratigraphic units (fence diagrams)
Postglacial (present to 12 500 years B.P.)	
Fraser River sediments	
Deltaic, distributary channel fill, and overbank deposits overlying postglacial estuarine and marine sediments in Fraser River delta	A
Salish sediments	
Lowland and mountain stream sediments, lacustrine, eolian, colluvial, landslide, beach and bog deposits	
Fraser glaciation (10 000 to 26 000 years B.P.)	
Capilano sediments	
Raised deltas, intertidal and beach deposits, glaciomarine sediments.	A
Found in the area west of Fort Langley beyond the area of Sumas	&
Drift. Contain no recognized till diamictons	C
Sumas drift	
Till, glaciofluvial, glaciolacustrine and ice-contact deposits	C
Fort Langley formation	
Interbedded marine, glaciomarine and glacial sediments. May include	A
fluvial deposits. The glacial sediments consist of till diamictons, ice-	&
contact deposits and proglacial deltas	B
Vashon drift	
At least three till diamictons, glaciofluvial and ice-contact deposits	D
Quadra sand	
Advance proglacial sediments of Fraser Glaciation, in part synchronous with, in part younger than, and in part older than Coquitlam Drift	C
Coquitlam drift	
Till diamicton and till-like mixtures of possible glaciomarine origin	D
Olympia nonglacial interval (25 800 to 36 200 years B.P.)	
Cowichan head formation	
Bog and swamp deposits interbedded with floodplain sediments overlying marine sediments	E

*Mappable units after Armstrong (1981).

2). For example, advancing and retreating glaciers gave rise to till and multi-till sequences, all of which were deposited in similar environments and share similar hydraulic properties.

HYDROGEOLOGY

The hydraulic behaviour of the precipitation falling on the Fraser Lowland is governed by the topography, the distribution of the surficial deposits, the climate and the vegetation. Of the precipitation not returned directly to the atmosphere through evaporation, part reaches the streams by direct overland flow, and the rest is retained on the land where it replenishes the soil moisture and eventually reaches the water table to replenish the ground-water reservoir. Recharge to ground-water reservoirs occurs mainly during winter months, when precipitation is high and the vegetation is dormant. At other times, especially during the growing season which varies from 170 to 210 days (British Columbia, Ministry of Environment, 1981), evapotranspiration may exceed the average seasonal precipitation. Records of water table fluctuations over the last 20 years indicate that annual recharge to the ground-water reservoirs is sufficient to balance consumptive losses.

Fully saturated geologic units that transmit significant quantities of water under ordinary hydraulic gradients are termed "aquifers"; those that are incapable of transmitting significant quantities under ordinary hydraulic gradients are defined as "aquicludes." Aquifers that occur near the land surface are classified as unconfined or water table aquifers; a water table forms their upper boundary. Aquifers that occur between aquitards such as clays, silts or tills are described as confined (Freeze and Cherry, 1979). In wells penetrating a confined aquifer the water level will rise above the top of the aquifer and the well is said to exist under artesian conditions. In several areas of the Fraser Lowland water levels rise above the land surface. In such cases, the well is called a flowing artesian well and the aquifer is said to exist under flowing artesian conditions.

The Fraser Lowland is underlain in most places by more than 300 m of surficial materials whose depositional environments are fluvial, marine, or glacial. As a result the deposited material varies significantly in its content of voids or pore spaces, and hence in its ability to store and transmit water. These deposits have been subdivided on the basis of grain size and depositional environment into five hydrostratigraphic units, labelled A to E as illustrated in the fence diagrams that accompany this report (Figs. 6, 9, 11, 14, 15, 18, 20, 22). The rest of the report involves an assessment of the hydrogeology of these units as well as hydrostratigraphic unit F, the bedrock.

Hydrostratigraphic Units

Hydrostratigraphic Unit A

Hydrostratigraphic unit A includes clay, stony clay and silty clays with varying stone content, as well as silty lenses, sandy silts and in some places marine shells. The proportion of clay is 10% to 50% ; silt, 35% to 75% ; and sand, 5% to 60% . In outcrop, the unit is characterized by a buff, weathered stony clay with blocky structure (Fig. 4). The material was mainly derived from ice sheets ending in the sea during the overall retreat of the last major Fraser Lowland ice. Although geologically younger, postglacial materials such as peat and floodplain deposits overlie the stony clays for part of the study area; these materials have not been separated as hydrostratigraphic units. Instead, they are included with unit A, as shown on the fence diagrams.

The unit extends, at or near the surface, throughout the central part of the study area, with the exception of where it is overlain by glaciofluvial ice-contact deposits, glaciofluvial deltas or thin patches of till left upon retreat of a final resurgence of glacier ice in the Fraser Lowland. The unit includes the Capilano sediments and Fort Langley formations described by Armstrong (1981). Within the study area, unit A is commonly less than 30 m thick. At or near its base, a sand layer with thin lenses of till forms a permeable unit which yields sufficient water for domestic use. Water analyses indicate that total dissolved solids are less than 120 mg/L, and pH ranges from 6 to 8.

Hydrostratigraphic Unit B

This unit is also of glaciomarine origin and consists of stony clays with shells. The stone content as well as the clay content seems, from the driller's logs, to be greater than in unit A. It is a unit of low permeability or an aquiclude and is found in the Langley Upland east of Abbotsford as well as in the valley of the Nicomekl and Serpentine rivers. In the Aldergrove test hole (Halstead, 1964) as much as 56 m of unit B was penetrated, while test holes in Milner and Fort Langley report as much as 90 m of this material.

Hydrostratigraphic Unit C

Hydrostratigraphic unit C consists mainly of glaciofluvial sand and gravel deposited by meltwater streams. Where the streams emptied into the sea, deltas were built up. With isostatic rebound of the land during and following deglaciation, these deltas are now elevated above sea level and cover large parts of townships 7 and 11. The largest raised delta, south of Langley, is approximately 30 km^2

Figure 4. Weathered stony clays, Bertrand Creek.

and has a flat surface with elevations ranging from 45 to 55 m above sea level. The deltaic sands and gravels are as much as 40 m thick and are locally covered by clay. A second large delta lies 65 km east and north of Langley, at an elevation of 85 m and covers an area of 24 km^2.

Meltwater streams issuing from stagnant melting ice masses in the vicinity of Sumas Mountain built up a plain of sand and gravel with lenses of till that occupies 20 km^2 south of Abbotsford and extends beyond the Abbotsford Airport. The plain extends westward into an area of hummocky topography with meltwater channels, outwash gravels and ice-contact morainal deposits south of Aldergrove.

All of these permeable materials overlie the stony clays (unit B) and contain water table aquifers. Discharge of ground water by springs (Fig. 5) is commonly observed along the edges of the deltas and is responsible for maintaining flows of Anderson and Fishtrap creeks and Salmon River. Discharge records available since 1965 for the mouth of Anderson Creek, representing a drainage area of 27.2 km^2, indicate average mean discharge during October of 0.320 m^3/s of ground water (Environment Canada, 1980).

Water quality for this unit is excellent; total dissolved solids are less than 120 mg/L and pH ranges from 6.5 to 7.6. Unit C is the source for many municipal and irrigation wells (Table C-1 in Appendix C) and also supplies a daily requirement of 130 L/s for a provincial trout hatchery.

Hydrostratigraphic Unit D

Hydrostratigraphic unit D includes those aggregates commonly referred to as till or diamictons, the components of which are brought together by a wide variety of glacial processes. The advancing glaciers moved southward down valleys within the Coast Mountains and overrode a landscape that had previously been fashioned by subaerial processes, especially river and stream action. Plenty of loose material was available for pickup and transport beneath and within the ice masses. Upon disappearance of the ice, tills consisting of heterogeneous mixtures of clay, silt, sand, gravel and boulders of varied shape and size were left.

Although the tills represent repeated invasions by glaciers in the Lowland, all are included in hydrostratigraphic unit D.

A till found at a depth of approximately 90 m below sea level in the Nicomekl and Serpentine valleys is representative of a penultimate glaciation. It is thin, averaging about 7 m, and rests on proglacial sand and gravel outwash below which stony clays are found. The upper surface of these stony clays is proposed as a former erosion surface

Figure 5. **Ground-water discharge along the toe of a delta, 4000 block, 192 Street, Surrey District Municipality.**

(Halstead, 1978). The rest of the tills shown in the fence diagrams are related to the last or Fraser glaciation, 11 000 to 26 000 years B.P. (Armstrong, 1981).

Tills are not continuous across the valleys within the Fraser Lowland, but till underlies the uplands at an elevation plus or minus 15 m in relation to present sea level. A multi-till sequence of till–outwash–till underlies the front of the Langley Upland. This ridge of till reaching a thickness in places of more than 100 m is interpreted as the wasting of a single glacier rather than as evidence of multiple glaciation. It can be traced eastward through the Langley Upland and is recognized in the Aldergrove test hole with a base elevation of 12 m and a thickness of 13 m.

Another till sequence is present, commonly separating two stony clays, and in places it is thin or missing or represented by glaciofluvial sediments only. This till forms a northeast-trending ridge within the Langley Upland, about 5 to 7 km east of the ridge described above. In the northeast corner of township 10 and the southeast corner of township 11, this till overrides or is deposited on fluvial sediments containing quantities of wood and peat.

A till that occurs at or near the surface in the Mount Lehman district covers much of township 14, and intertill segments seem to be associated with meltwater channels and extensive areas of outwash sand and gravel that cover the greater part of townships 13 and 16. Because of its stratigraphic position, this till is obviously related to a final stage of ice advance in the valley described as the Sumas Stade (Armstrong, 1981).

Tills and till complexes of this hydrostratigraphic unit constitute major confined aquifer systems with water quality characteristically of the sodium-bicarbonate type and total dissolved solids less than 500 mg/L. Because ample supplies of good quality ground water are available in till sequences, within the top 90 m of drilling, test holes rarely continue to depths where older tills are found.

Hydrostratigraphic Unit E

All the materials included in units A to D were deposited by processes related to retreating ice masses and sea level changes brought about by glacioclimatic events accompanying the Fraser Glaciation. Unit E comprises older materials, mostly marine sediments interbedded with estuarine and fluvial deposits consisting of fine sand, silt and clayey silts. All drill holes that penetrate to depths of more than 90 m have found these materials. Flow systems in this unit transmit water for which residence time has been considerable. Therefore, water quality is characteristically of the sodium-chloride type, and total dissolved solids range from 750 to 6000 mg/L.

Hydrostratigraphic Unit F

Unit F consists of bedrock. Within the Fraser Lowland bedrock is usually found at depths greater than 300 m, but evidence of bedrock "highs" is indicated on the fence diagrams for townships 10, 14 and 16 (Figs. 14, 20 and 22, in pocket). Bedrock is the source of ground water for areas north of the Fraser River in townships 12 and 15 as well as in upland areas such as Ryder Lake, Chilliwack, Sumas and Vedder mountains.

Distribution of Aquifers

Township 1

Sunnyside-Whiterock Upland occupies much of township 1. The upland rises to elevations of 114 m, dropping off sharply to sea level on the south and west sides and to the Nicomekl-Serpentine Valley on the north. Eastward the upland extends into township 7. The distribution of hydrostratigraphic units within the township is illustrated by the fence diagram and well location map in Figure 6 (in pocket).

The upland is capped by lodgment till, which in places may be as much as 30 m thick. The till has been deposited on an upland erosion surface, underlain by fluvial sands and silts that extend vertically to or near sea level. A major aquifer underlies the sands and silts and consists of gravel, sand and lenses of till from proglacial deposition. All wells within this horizon yield water with low total dissolved solids, commonly less than 155 mg/L. Static water levels do not rise above the top of the aquifer, which suggests the aquifer is unconfined. A number of production wells (Table C-1, Nos. 3 and 4) have been drilled and, prior to 1972, provided an annual average 4.0×10^6 m^3 of good quality ground water. Since then, a storage tank with a capacity of 10.4×10^3 m^3 was built at 22 Ave. and 145 St. to meet increased demands from residential growth, and now water from the Greater Vancouver Water District supplies much of the upland.

Within the boundaries of the city of White Rock (Table C-1, Well No. 5) ground water is the source of supply. During summer months, peak demands may reach as much as 22.7×10^3 m^3/day. Excepting production wells for municipal supplies, wells are mainly for agricultural use, in particular greenhouse culture.

A local flow system in section 24, within the northeast part of the upland, discharges under artesian conditions. One well, more than 30 m deep, discharges directly into trout-rearing ponds at a rate of 30 L/s (Fig. 7). This isolated flow system may have resulted from deposition of a mass of flow-till from a melting ice mass that grounded on the upland.

The northern part of the township lies within the Nicomekl-Serpentine Valley, which is a discharge area for regional ground-water flow. Flowing artesian water is found in all wells, and depths may exceed 120 m. Water quality is contingent upon the distribution of chlorides

Figure 7. Flowing artesian well, 16510 – 32 Ave. following completion in August 1969.

and sulphates in the flow system, which is sluggish owing to diurnal tidal changes in adjacent Mud Bay (Halstead, 1978).

In 1962, a test hole was drilled for oil and gas exploration in section 13. Drilling continued to a depth of 3312 m before the hole was abandoned as dry, but drill stem tests indicated freshwater at 636 m.

Township 2

Township 2 occupies a large part of Newton Upland together with part of the Serpentine Valley. Water from the Greater Vancouver Water District is distributed throughout the upland, and Figure 8 shows the location of existing drilled wells and test holes.

The upland is capped with 3 to 30 m of marine and glaciomarine stony silty clay that overlies a sequence up to 75 m thick of lodgment and flow tills with lenses and interbeds of stratified glaciofluvial sand and gravel. Groundwater supplies are recovered from the till sequences (hydrostratigraphic unit D). Drilling in the upland area is not continued to greater depths. A wildcat test hole, drilled in 1951 in section 21, reported unconsolidated materials continuing to a depth of 390 m. The top 23 m consisted of 3 m of marine silty clays overlying 20 m of a till sequence. At a depth of 18 to 20 m, gravels yielded water at a rate of 8 L/s. The potential of the till sequence is further documented at Green Timbers Forest Nursery, 9800-140 St. (Table C-1, Well No. 2), which lies just north of sections 33 and 34, immediately north of township 2. Since 1935, the nursery has used ground water for irrigation. The original well was dug to a depth of 19 m, but in 1962, a 305-mm diameter drilled well was completed with a 100-slot screen set at a depth of 20.7 to 32.2 m. This was followed, in 1977, by a second well of 203-mm diameter, developing aquifer materials within till sequences at depths of 34.3 to 48 m. In 1980, a third well, 203 mm in diameter, was screened from 29 to 35 m. The three drilled wells were pumped at rates of 15 L/s, 9.4 L/s and 15.7 L/s, respectively. The aquifers are all within the upland recharge zone and yield water qualities with low total dissolved solids.

In the southeast part of the township a number of test holes were drilled by rotary methods in 1965 to define potential aquifers within the Nicomekl–Serpentine Valley. Test holes in sections 1 and 2 were continued to depths in excess of 300 m and reached bedrock at 302 and 255 m, respectively. Within Serpentine Valley, confined groundwater conditions are found in lenses of fluvial materials within the mainly marine valley fill sediments (hydrostratigraphic unit E).

Flowing artesian wells, adjacent to the southern boundary of Newton Upland, yield ground water from local flow systems originating in the upland area; hence the quality is excellent. Elsewhere, in sections 1 and 2, especially along 50th Ave., regional flow systems provide ground water with chlorides in excess of 900 mg/L (Fig. 34, in pocket).

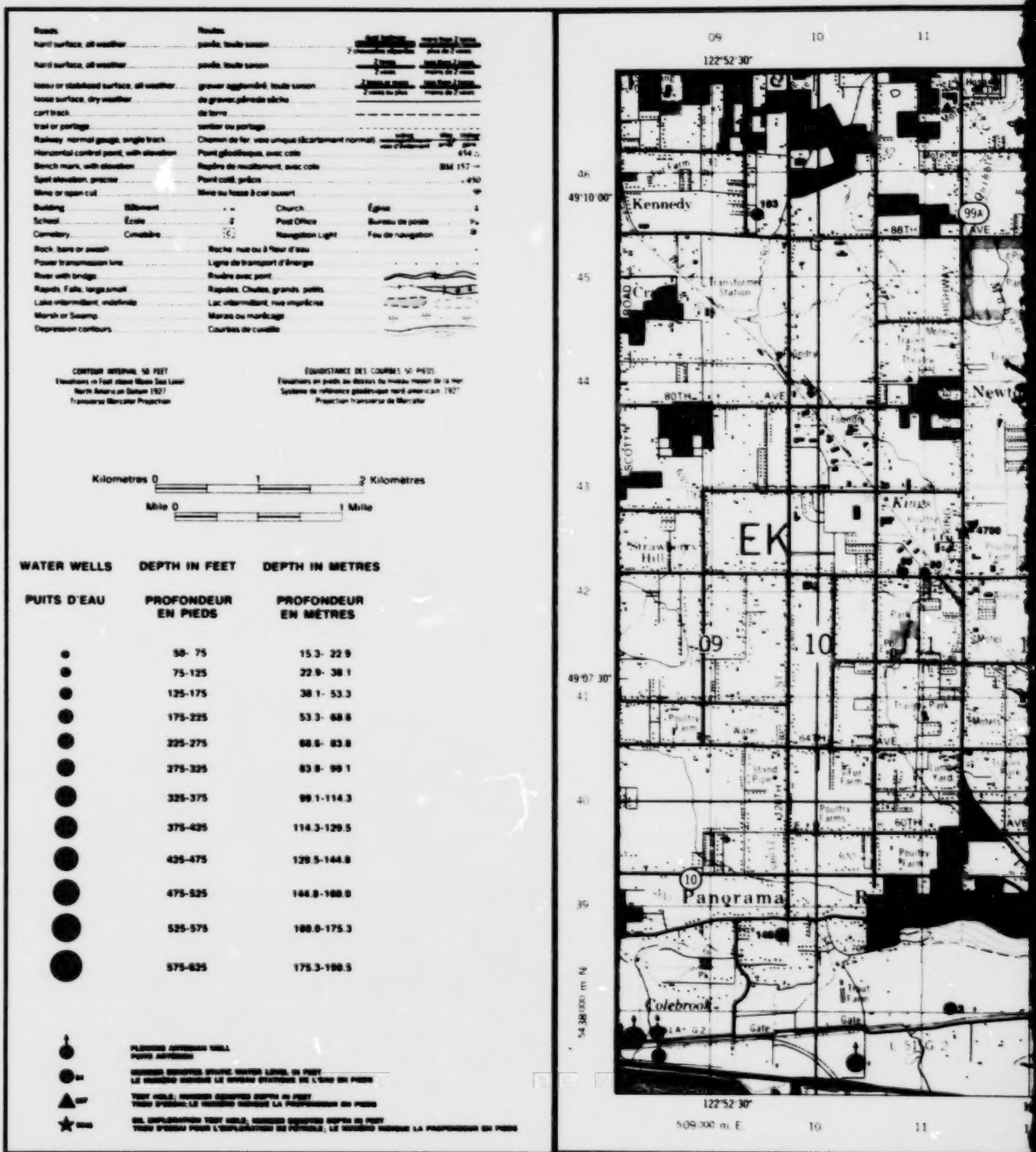
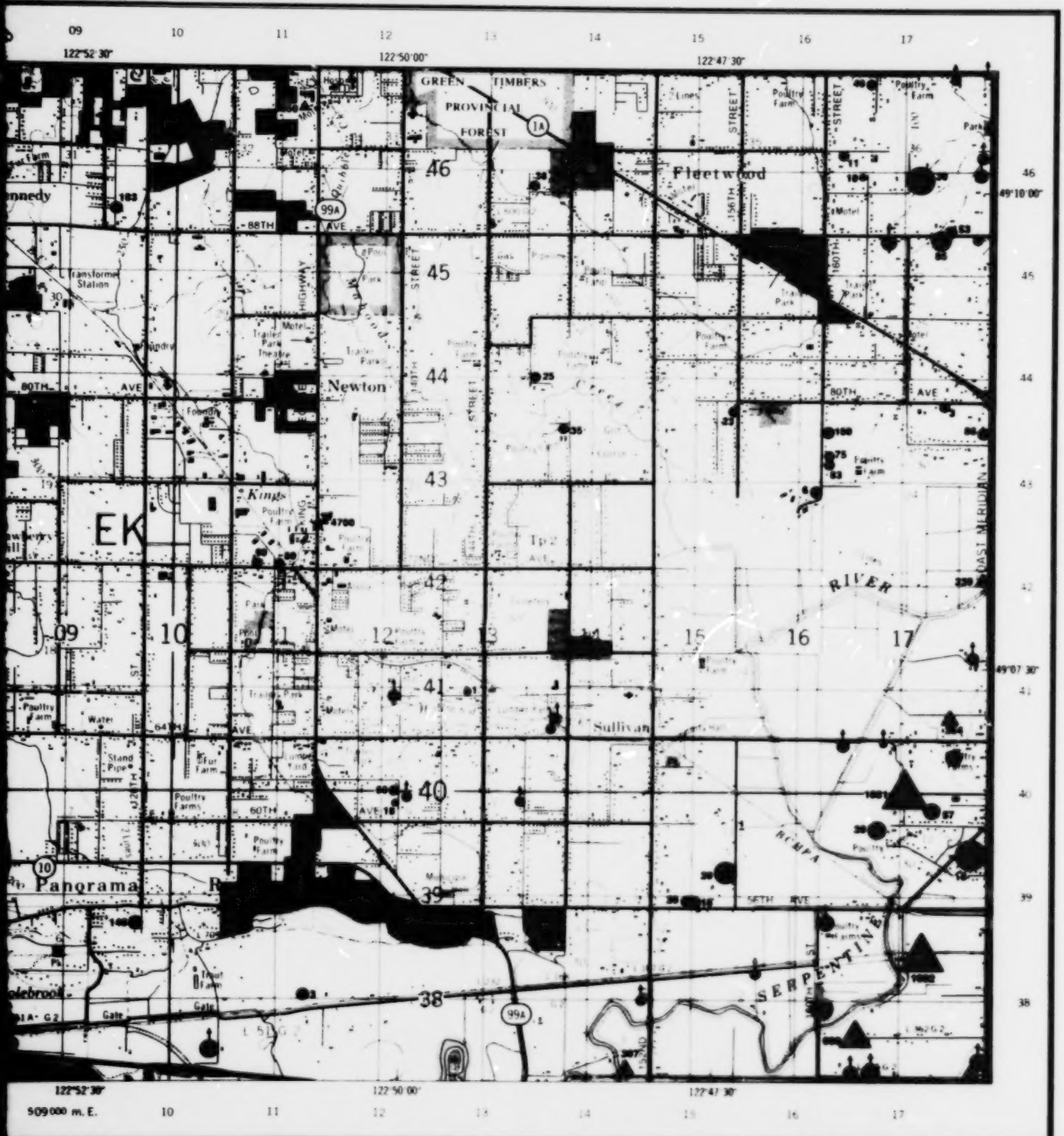


FIGURE 8. WELL LOCATIONS, TOWNSHIP 2, SURREY D

FIGURE 8. EMPLACEMENT DES PUITS, CANTON 2, MUNICIPA



ÉTABLI PAR LA DIVISION DE DESSIN DES
MINISTÈRE DE L'ENVIRONNEMENT 1980

IMPRIMÉE PAR LA DIRECTION DES LEVÉS ET DE LA CARTOGRAPHIE
MINISTÈRE DE L'ÉNERGIE DES MINES ET DES RESSOURCES

ATIONS, TOWNSHIP 2, SURREY DISTRICT MUNICIPALITY
ES PUITS, CANTON 2, MUNICIPALITÉ DU DISTRICT DE SURREY

Township 7

The southeast part of township 7 includes the front of Langley Upland. Extending from there westward is a raised delta that largely covers the northwest quarter of the township. Two lowlands, Hazelmere and Nicomekl valleys, which are separated by an eastward extension of Sunnyside Upland from township 1, occupy the western half of the township. Figure 9 (in pocket) illustrates the distribution of the hydrostratigraphic units, together with a map showing well locations. The most productive hydrostratigraphic unit (unit C) is the water table aquifer consisting of the raised delta sand and gravel. This delta covers an area of approximately 25 km^2 with an average thickness of 30 m. Recharge to the water table by winter precipitation is immediate, and Figure 10 shows hydrographs for typical years, ranging from below to above normal precipitation. Water tables are also exposed in gravel pit excavations. A number of production wells for irrigation and municipal use (Table C-1, Nos. 13, 14, 15, 16 and 17) have been completed in the delta, and most are designed to yield in the order of 35 L/s. However, because the grain size is poorly sorted, aquifer yields vary considerably over short distances, and many test holes must be drilled prior to establishing a well field. Production from the Brookswood municipal wells in section 27 totaled more than 7.1×10^6 m^3 in 1976. For irrigation purposes the nearby B.C. Ministry of Forests nursery at 3605-192 St. requires approximately 126 L/s, and a yearly consumption of 1.4×10^6 m^3 has been recorded. Thus, annual irrigation and municipal use, excluding numerous domestic wells and ground-water discharge to Anderson Creek and Campbell River, may account for more than 8.5×10^6 m^3 of ground water from this water table aquifer.

A test hole was completed to a depth of 242 m in section 27 within the Langley City well field. The top 24 m of deltaic sand and gravel constitutes an unconfined aquifer acting as a recharge area and is underlain by fluvial interbedded silty clays at the base of the delta. A water-bearing sand layer found between 62 and 68 m is underlain by 82 m of stony clays. Till-like material found from 150 to 152 m can be traced westward underlying the Nicomekl-Serpentine Valley, and this in turn is underlain by 10 m of sand and gravel that yield ground water with sodium and chloride concentrations in excess of 200 mg/L.

Within that part of township 7 that is included in Langley Upland, productive aquifers are found in the multi-till sequences. These have proven to be as much as 103 m thick in test holes that have been drilled in gravel pits at 0 and 8th avenues.

Confined aquifers in Hazelmere Valley supply good quality ground water, with total dissolved solids ranging from 250 to 350 mg/L. The wells are flowing artesian and the aquifers are found at depths in the order of 90 to 100 m. One such well in section 7 formerly supplied more than 2.0×10^6 m^3 per year for a water distribution system in the Grandview district of south Surrey District Municipality. Forty test holes were drilled in the valley between 1910 and 1912 and only those in section 8, at Hall's Prairie School, were nonproductive. A test hole drilled to a depth of 338 m at Peace Arch Park, Blaine Border crossing in section 6 failed to find any water-bearing materials.

Tertiary bedrock was found at a depth of 466 m in a hole drilled for oil and gas exploration in section 4, in 1955.

Township 8

Clayton Upland, a rolling, hilly surface 60 to 90 m above sea level, occupies a large part of township 8. This upland trends northeast and is nearly ellipsoidal, bounded on the northwest by Serpentine Valley, on the north by the lowlands bordering the Fraser River, and on the southeast and south by the Nicomekl Valley. A western extension of the upland, surrounding the settlement of Surrey Centre, is lower, 38 m above sea level, and is separated from the main body of the upland by a broad saddle 17 m above sea level.

The fence diagram, Figure 11 (in pocket), shows a thick series of tills underlying the upland. In places, drill holes may penetrate more than 60 m of massive lodgment-type tills, and elsewhere multi-till sequences of similar thickness are found. Apparently, the upland was formerly a hilly erosion surface upon which ice stagnated, and the tills are products of the melting processes related to the wasting stages. The till sequences become thinner near the edge of the upland, perhaps owing to marine erosion and slumping. Test holes in sections 9 and 14 penetrate upwards of 60 m of multi-till sequences.

Within Clayton Upland a number of test holes were drilled in 1959 in search of ground water to meet municipal needs, but sufficient volumes were not available to develop supplies in the range of 7.5 L/s. Commonly, good quality ground water for domestic and farm needs, with total dissolved solids less than 175 mg/L, is found in drill holes that range in depth from 30 to 60 m. In SW 1/4 section 9, a well field formerly supplied the Cloverdale area from aquifers below the multi-till sequences. One test hole was continued to a depth of 377 m, penetrating bedrock at approximately 336 m.

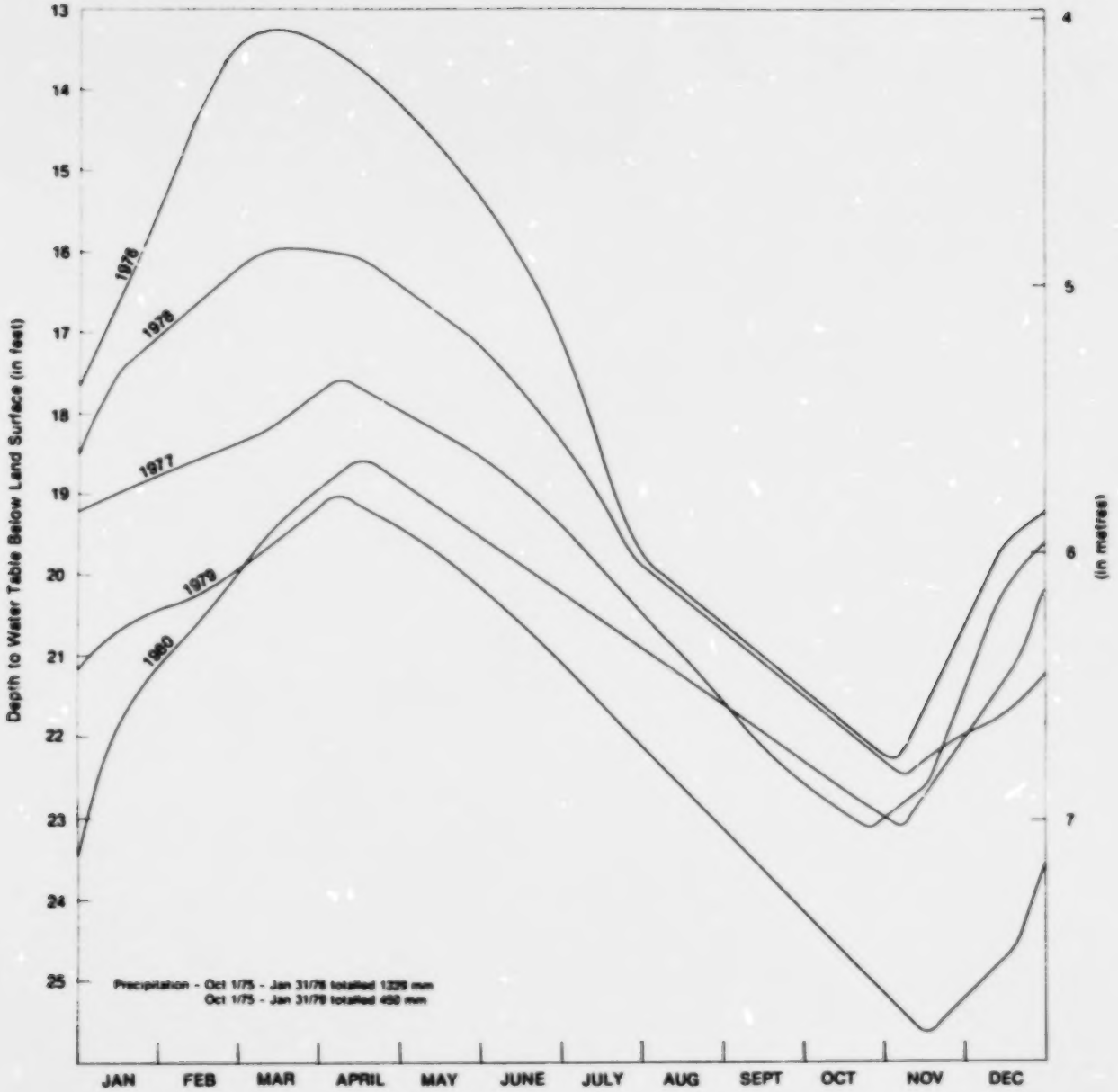


Figure 10. Hydrographs, observation well, Section 27, Township 7, Surrey District Municipality.

In the southeast, the City of Langley was dependent upon ground water from individual wells prior to 1960. All the wells were flowing artesian, ranged up to 100 m in depth and produced from lenses of permeable materials within the valley sediments. In 1958, a test hole was drilled in the centre of the city, to a depth of 355 m, and it penetrated unconsolidated materials the entire depth.

In SE 1/4 section 5 a test hole was drilled to the top of bedrock at 300 m. Samples were examined and sieved for a stratigraphic record and the log of this hole provided a framework for much of the correlation of the materials filling the Nicomekl–Serpentine Valley. At 31.5 m, shells were found and radiocarbon dated at 10 430 ± 150 years B.P. Ground-water analyses, at a depth of 140 m, showed chloride values of 480 mg/L.

The Serpentine Valley is mostly filled with marine sediments up to 300 m in depth. Along the west side, adjacent to Newton Upland, local flow systems supply ground water under artesian pressure to wells drilled up to 60 m. One of these wells (Fig. 12) in section 30, drilled to a depth of 34 m, has been flowing since 1957 at a rate greater than 11 L/s, and presently supplies a trout-rearing farm. In SW 1/4 section 20, a production well was drilled to a depth of 140 m, where an artesian aquifer yields good quality ground water at the rate of 15 L/s. Extending north into Serpentine Valley, all aquifers are confined within a thick sequence of marine sediments, and water quality deteriorates. In the area just west of Port Kells, ground waters with total dissolved solids greater than 3000 mg/L are found at depths of 90 m. The high total dissolved solids probably reflect slow-moving water in a regional flow system.

Township 9

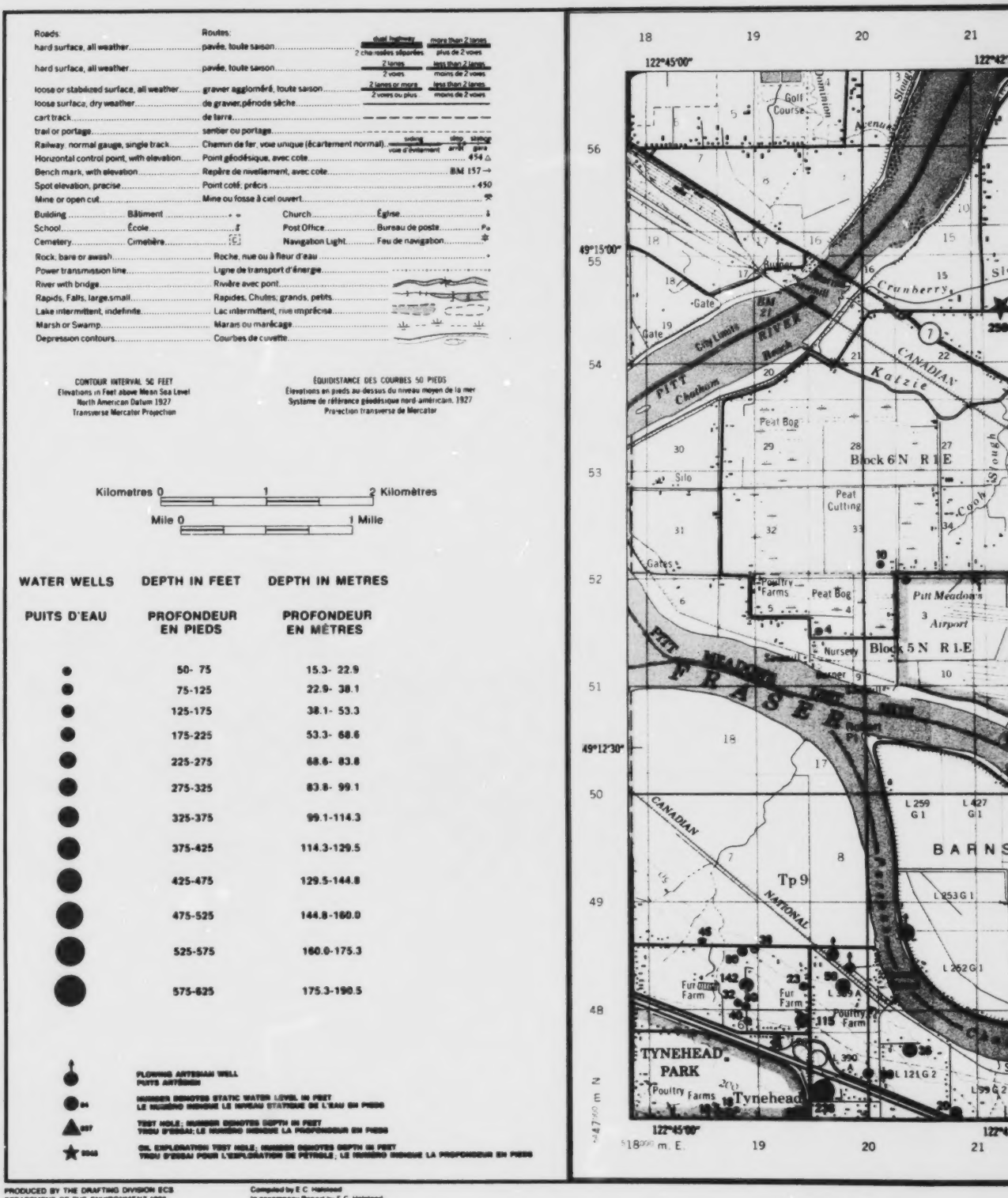
The hydrogeology of sections 1 to 6, south of the Fraser River, is illustrated in Figure 11 and well locations are shown on Figure 13.

In sections 1, 2 and 3, where sand and gravel are present at the surface in thicknesses up to 10 m, sandpoints and shallow dug wells yield sufficient water for domestic supplies. A 205-m well in section 1, and test holes reaching depths of 193 and 165 m in sections 2 and 3 penetrated marine silty clays in which lenses of silty sand yielded saline water. Within section 4, wells reaching depths of 90 to 120 m provide water with total dissolved solids in excess of 1000 mg/L. Residents in sections 5 and 6 depend on ground water from wells in aquifers in a multi-till sequence. Depths commonly range from 40 to 70 m, except at Anniedale School, where drilling was continued to 135 m before a suitable aquifer was found.

Figure 12. Flowing artesian well, 172 Street, Section 30, Township 8, Surrey District Municipality.

On Barnston Island, a well at the ferry landing reaches a depth of 84 m and yields good quality water with chlorides in the range of 50 mg/L, but at the Indian Reserve, test holes to comparable depths found chlorides in excess of 800 mg/L. Elsewhere on Barnston Island, sand and gravel up to 30 m thick underlying floodplain silty clays yield adequate domestic supplies.

North of the Fraser River, most of the rest of township 9 lies within the Pitt Polder area, in which oil and gas exploration holes indicate more than 300 m of unconsolidated materials overlying bedrock. A test hole drilled in 1949 found only salty water and was abandoned at a depth of 180 m. Similarly, a test hole drilled to a depth of 152 m at the intersection of Dewdney Trunk Road and 206 St. in 1961 was abandoned. West of Pitt Meadows Airport, sand and gravel underlying floodplain silty clays were found in three wells ranging in depth from 18 to 28 m and can be developed to yield up to 40 L/s of ground water for irrigation. After one year, water qualities in these irrigation wells had deteriorated to saline water with chlorides exceeding 1300 mg/L.


Roads: Routes:
hard surface, all weather ... pavée, toute saison
dual highway ... 2 chaussées séparées
more than 2 lanes ... plus de 2 voies
2 lanes ... 2 voies
less than 2 lanes ... moins de 2 voies
hard surface, all weather ... pavée, toute saison
loose or stabilized surface, all weather ... gravier aggloméré, toute saison
2 lanes or more ... 2 voies ou plus
loose surface, dry weather ... de gravier, période sèche
cart track ... de barre
trail or portage ... sentier ou portage
Railway, normal gauge, single track ... Chemin de fer, voie unique (écartement normal)
siding ... voie d'évitement
stn. ... gare
Horizontal control point, with elevation ... Point géodésique, avec cote ... 454 △
Bench mark, with elevation ... Repère de nivellement, avec cote ... BM 157 →
Spot elevation, precise ... Point coté, précis ... • 450
Mine or open cut ... Mine ou fosse à ciel ouvert
Building ... Bâtiment
Church ... Église
School ... École
Post Office ... Bureau de poste ... P.O.
Cemetery ... Cimetière ... (C)
Navigation Light ... Feu de navigation
Rock, bare or awash ... Roche, nue ou à fleur d'eau
Power transmission line ... Ligne de transport d'énergie
River with bridge ... Rivière avec pont
Rapids, Falls, large, small ... Rapides, Chutes, grands, petits
Lake intermittent, indefinite ... Lac intermittent, rive imprécise
Marsh or Swamp ... Marais ou marécage
Depression contours ... Courbes de cuvette
CONTOUR INTERVAL 50 FEET
Elevations in Feet above Mean Sea Level
North American Datum 1927
Transverse Mercator Projection
ÉQUIDISTANCE DES COURBES 50 PIEDS
Élévations en pieds au-dessus du niveau moyen de la mer
Système de référence géodésique nord-américain, 1927
Projection transverse de Mercator
Kilometres 0 1 2 Kilometres
Mile 0 1 Mile
WATER WELLS
PUITS D'EAU
DEPTH IN FEET
PROFONDEUR EN PIEDS
DEPTH IN METRES
PROFONDEUR EN MÈTRES
50- 75 15.3- 22.9
75-125 22.9- 38.1
125-175 38.1- 53.3
175-225 53.3- 68.6
225-275 68.6- 83.8
275-325 83.8- 99.1
325-375 99.1-114.3
375-425 114.3-129.5
425-475 129.5-144.8
475-525 144.8-160.0
525-575 160.0-175.3
575-625 175.3-190.5
FLOWING ARTESIAN WELL
PUITS ARTÉSIEN
NUMBER DENOTES STATIC WATER LEVEL IN FEET
LE NUMÉRO INDIQUE LE NIVEAU STATIQUE DE L'EAU EN PIEDS
TEST HOLE; NUMBER DENOTES DEPTH IN FEET
TROU D'ESSAI; LE NUMÉRO INDIQUE LA PROFONDEUR EN PIEDS
OIL EXPLORATION TEST HOLE; NUMBER DENOTES DEPTH IN FEET
TROU D'ESSAI POUR L'EXPLORATION DE PÉTROLE; LE NUMÉRO INDIQUE LA PROFONDEUR EN PIEDS
18 19 20 21
122°45'00"
49°15'00"
49°12'30"
56 55 54 53 52 51 50 49 48
Golf Course
Dominion
Sturgeon
Avenue
Cranberry
Gate
City Limits
RIVER
Bench
PITT
Chatham
CANADIAN
Katzie
Peat Bog
Block 6 N R 1 E
Silo
Peat Cutting
Cook Slough
Gates
Poultry Farms
Pitt Meadows
Airport
Nursery
Block 5 N R 1 E
PITT MEADOWS
FRASER
CANADIAN
NATIONAL
Tp 9
BARNS
L 259 G 1
L 427 G 1
L 253 G 1
L 262 G 1
Fur Farm
Poultry Farm
TYNEHEAD PARK
Tynehead
L 121 G 2
5489000 m. E.
5487000 m N

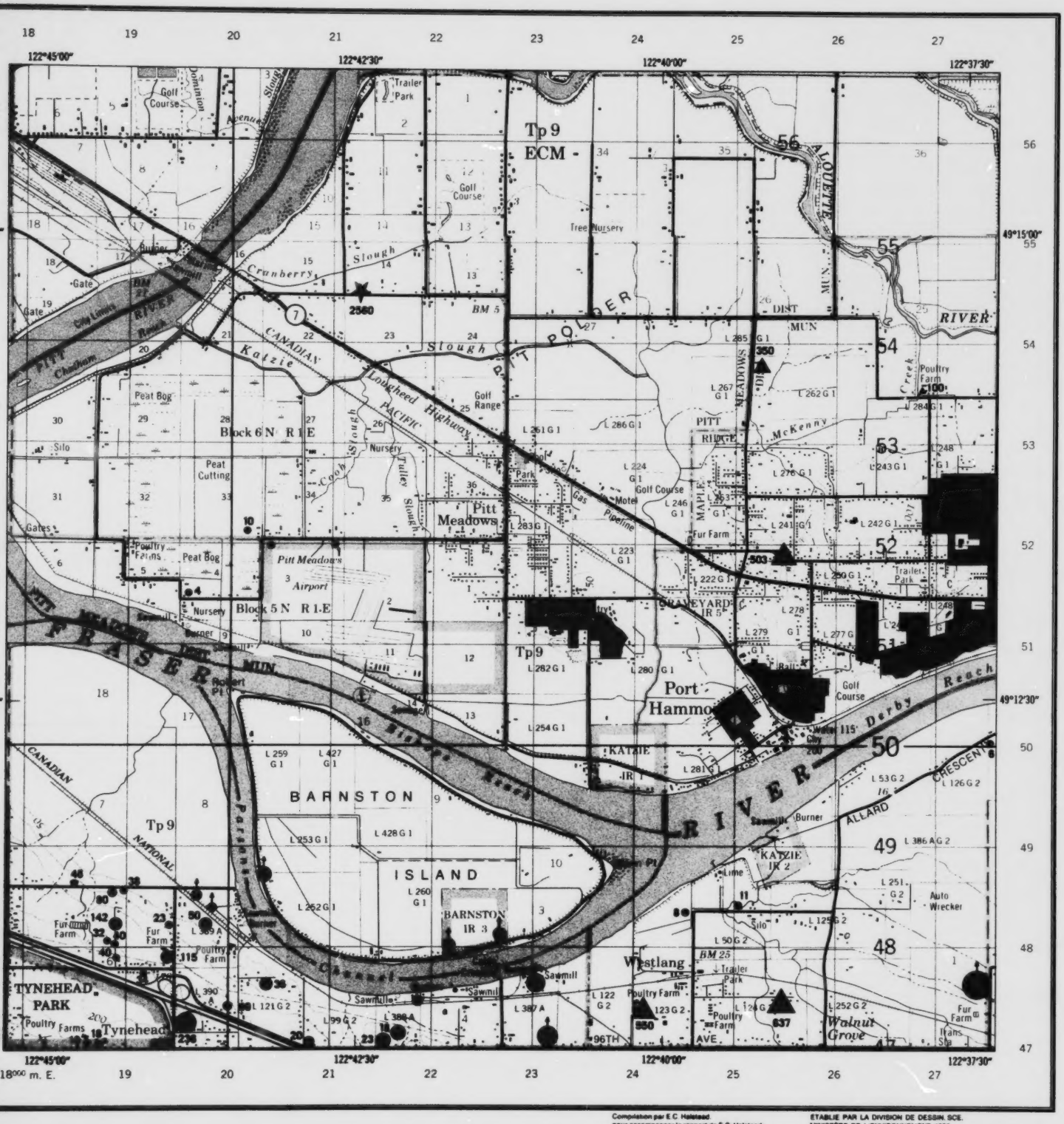
PRODUCED BY THE DRAFTING DIVISION ECS
DEPARTMENT OF THE ENVIRONMENT 1983

PRINTED BY THE SURVEYS AND MAPPING BRANCH
DEPARTMENT OF ENERGY MINES AND RESOURCES

Compiled by E C Halstead
to accompany Report by E C Halstead,
National Hydrology Research Institute,
Inland Waters Directorate

FIGURE 13. WELL LOCATIONS, TOWNSHIP 9, SURREY-PITT

FIGURE 13. EMPLACEMENT DES PUITS, CANTON 9, MUNICIPALITÉS DE


122°45'00"
122°42'30"
122°40'00"
122°37'30"
49°15'00"
49°12'30"
Tp 9
ECM -
Golf Course
Trailer Park
Free Nursery
Cranberry Slough
Block 6 N R 1 E
Block 5 N R 1 E
Peat Bog
Peat Cutting
Nursery
Poultry Farms
Pitt Meadows Airport
Pitt Meadows
Golf Range
Golf Course
Motel
Gas Pipeline
Fur Farm
Graveyard IR 5
Trailer Park
Port Hammond
Derby Reach
Fraser River
Pitt River
Alouette River
Canadian National
Lougheed Highway
Pacific Highway
Barnston Island
Barnston IR 3
Katzie IR 2
Tynehead Park
Tynehead
Westlang
Walnut Grove
Auto Wrecker
Sawmill
Lime
Silo
Crescent
Allard
96th Ave.
Pitt Polder
Pitt Meadows
Maple Ridge
McKenny
Creek
Slough
Valley
Dist. Mun.
Mun.
Dist.
Parsons
Channel
Bridge
Ferry
Burner
Poultry Farm
Fur Farm
Trans Sta
Airport
Golf
Park
Ditch
Gates
Silo
Lime
Sawmill
Auto Wrecker
Trailer Park
Poultry Farms
Peat Bog
Peat Cutting
Nursery
Golf Course
Golf Range
Motel
Gas Pipeline
Fur Farm
Graveyard

Township 10

The rolling upland surface of township 10 reaches a topographic high of 138 m in section 23. Surface drainage from this upland to the west is via Murray Creek and its tributaries. Campbell River drains the southwest part through an abandoned meltwater channel, and Bertrand Creek provides for the surface drainage of the southeastern part. The township is largely farm land, with the exception of industrial development along the Fraser Highway. The correlation of more than 1000 well records provides the hydrostratigraphic relationships and well location map shown on Figure 14 (in pocket).

In the early 1900s, township 10 was the site of test drilling for oil and gas exploration. One hole drilled in section 27 was continued to a depth of 1745 m and penetrated Tertiary bedrock at 137 m. Exploration drilling in section 24 found bedrock at 85 m. This bedrock "high" of Tertiary sandstone and siltstone with lenses of organic material and coal has also been found when drilling for domestic water supplies, but only one well had penetrated the bedrock 35 m before it was abandoned.

In 1970, a test hole was drilled in section 11 to a depth of 343 m. The 210 m of surficial materials correlate with those in deep test holes drilled in townships 7 and 13. A sequence of stony clays with interbedded fluvial sand and gravel containing some till lenses overlie lodgment and flow tills that have been deposited in some areas in moraine-like ridges up to 100 m thick. These unconsolidated materials make up the top 100 m or more and contain the major aquifers (hydrostratigraphic unit D), hence drilling throughout most of the township does not exceed this depth. Fluvial sand and gravel extending westward from the topographic high in section 23 provide the most widespread recharge area in the township. The sand and gravel decrease in thickness westward and are overlain by a confining stony clay throughout sections 29 and 32, where domestic supplies are obtained from flowing artesian wells up to 40 m deep.

Most of the ground water in township 10 is the sodium-bicarbonate type with total dissolved solids of less than 250 mg/L. In the southeast corner, especially in sections 12 and 13, stony clays up to 100 m or more overlie a thin till or fine sand, below which a regional flow system yields ground water with excessive chlorides. In this area, a number of test holes, the deepest being 146 m, have been abandoned because of chlorides exceeding 2000 mg/L.

Township 11

The topography of township 11 consists of uplands and valleys modified by drainage from tributary streams flowing north to join the Fraser River. Figure 15 (in pocket) illustrates the distribution of hydrostratigraphic materials and the location of wells.

Extensive deltaic deposits along the northwest edge of Langley Upland, representing hydrostratigraphic unit C, constitute a water table aquifer locally more than 30 m thick. Observation well data (Fig. 16) indicate annual water table fluctuations in the order of 3.3 m, with recharge during the months of November to March. Apart from domestic use, a number of wells have been installed to serve subdivisions and irrigation needs (Wells Nos. 21 to 25, Table C-1). Elsewhere in the uplands, wells are commonly drilled to depths not exceeding 60 m, before intersecting hydrostratigraphic unit D, which is also found in NW 1/4 section 4 at depths of less than 30 m. The ground water is under sufficient artesian pressure to flow.

Fort Langley Upland is underlain by 18 m of sand and gravel, from which individual wells recover sufficient water for household use. More recently a water system has been installed, whereby ground water from two municipal wells on 88th Avenue, one 133 m and the other 20.3 m deep, provided more than 6.5×10^4 m^3 during 1981 (Table C-1, Well No. 10).

The deepest wells in the Fraser Lowland are found in sections 18 and 19, drilled to depths of 276 and 278 m, respectively, to intersect a confined aquifer of coarse gravel, yielding good quality ground water. However, a test hole in NW 1/4 section 18, penetrating 340 m of silty clays with shells, failed to produce water.

Most of the wells in Glen Valley are flowing artesian, and quantities suffice for trout farming.

Township 12

Most of township 12 lies north of the Fraser River and is included in Maple Ridge District Municipality. The locations of wells drilled are shown in Figure 17 and that part of the township south of the Fraser River is shown in Figure 15 (in pocket). Northwest of Fort Langley in sections 5, 6 and 7, test holes have been drilled to depths of 195 m only to find ground water with chloride concentrations in the range of 500 mg/L.

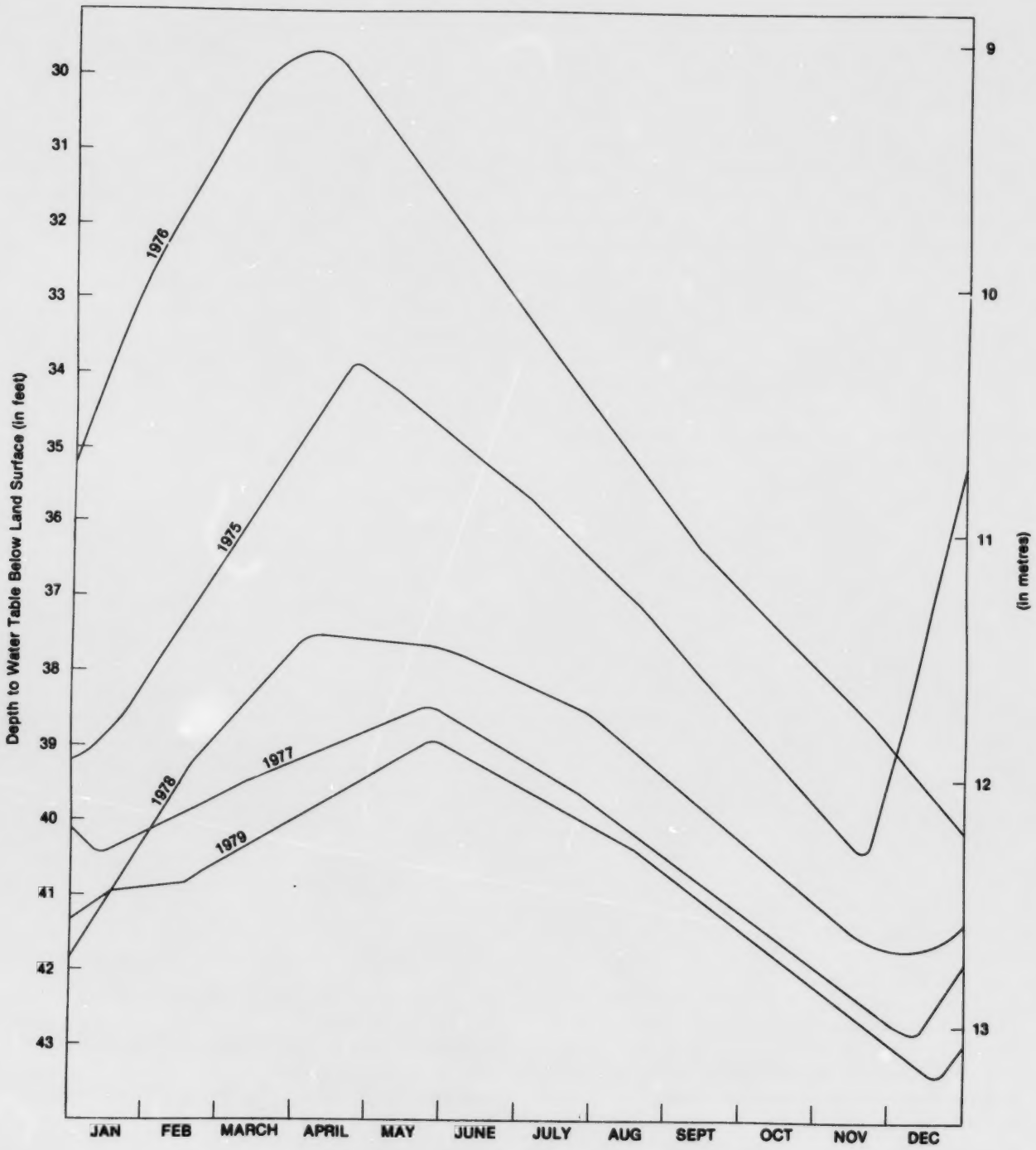
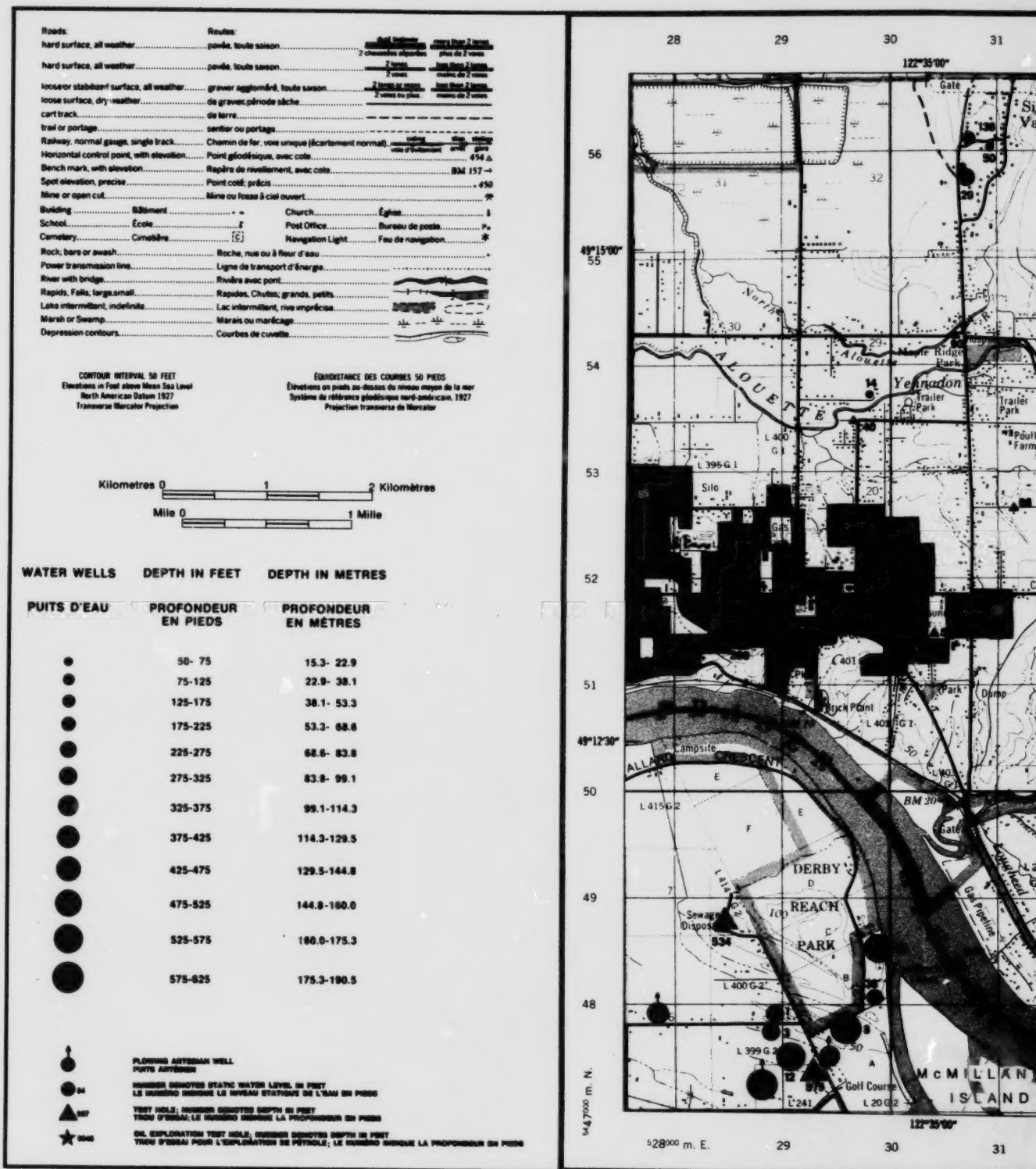


Figure 16. Hydrographs, observation well, Section 4, Township 11, Langley District Municipality.


Roads: Routes:
hard surface, all weather ... pavée, toute saison
hard surface, all weather ... pavée, toute saison
loose or stabilized surface, all weather ... gravier aggloméré, toute saison
loose surface, dry weather ... de gravier, période sèche
cart track ... de terre
trail or portage ... sentier ou portage
Railway, normal gauge, single track ... Chemin de fer, voie unique (écartement normal)
Horizontal control point, with elevation ... Point géodésique, avec cote
Bench mark, with elevation ... Repère de nivellement, avec cote
Spot elevation, precise ... Point coté; précis
Mine or open cut ... Mine ou fosse à ciel ouvert
Building ... Bâtiment
School ... École
Cemetery ... Cimetière
Church ... Église
Post Office ... Bureau de poste
Navigation Light ... Feu de navigation
Rock; bare or awash ... Roche, nue ou à fleur d'eau
Power transmission line ... Ligne de transport d'énergie
River with bridge ... Rivière avec pont
Rapids, Falls, large, small ... Rapides, Chutes; grands, petits
Lake intermittent, indefinite ... Lac intermittent, rive imprécise
Marsh or Swamp ... Marais ou marécage
Depression contours ... Courbes de cuvette
CONTOUR INTERVAL 50 FEET
Elevations in Feet above Mean Sea Level
North American Datum 1927
Transverse Mercator Projection
ÉQUIDISTANCE DES COURBES 50 PIEDS
Élévations en pieds au-dessus du niveau moyen de la mer
Système de référence géodésique nord-américain, 1927
Projection transverse de Mercator
Kilometres 0 1 2 Kilomètres
Mile 0 1 Mile
WATER WELLS DEPTH IN FEET DEPTH IN METRES
PUITS D'EAU PROFONDEUR EN PIEDS PROFONDEUR EN MÈTRES
50- 75 15.3- 22.9
75-125 22.9- 38.1
125-175 38.1- 53.3
175-225 53.3- 68.6
225-275 68.6- 83.8
275-325 83.8- 99.1
325-375 99.1-114.3
375-425 114.3-129.5
425-475 129.5-144.8
475-525 144.8-160.0
525-575 160.0-175.3
575-625 175.3-190.5
FLOWING ARTESIAN WELL
PUITS ARTÉSIEN
NUMBER DENOTES STATIC WATER LEVEL IN FEET
LE NUMÉRO INDIQUE LE NIVEAU STATIQUE DE L'EAU EN PIEDS
TEST HOLE; NUMBER DENOTES DEPTH IN FEET
TROU D'ESSAI; LE NUMÉRO INDIQUE LA PROFONDEUR EN PIEDS
OIL EXPLORATION TEST HOLE; NUMBER DENOTES DEPTH IN FEET
TROU D'ESSAI POUR L'EXPLORATION DE PÉTROLE; LE NUMÉRO INDIQUE LA PROFONDEUR EN PIEDS
28 29 30 31
122°35'00"
49°15'00"
49°12'30"
56 55 54 53 52 51 50 49 48
Gate
Yennadon
Trailer Park
Maple Ridge Park
ALOUETTE
Silo
Gas
Campsite
CREEK
DERBY REACH PARK
Sewage Disposal
Golf Course
McMILLAN ISLAND
Gas Pipeline
Dump
BM 20
L 400 G 1
L 395 G 1
L 401
L 415 G 2
L 414
L 400 G 2
L 399 G 2
L 241
L 20 G 2
5447000 m. N.
528000 m. E.
122°35'00"

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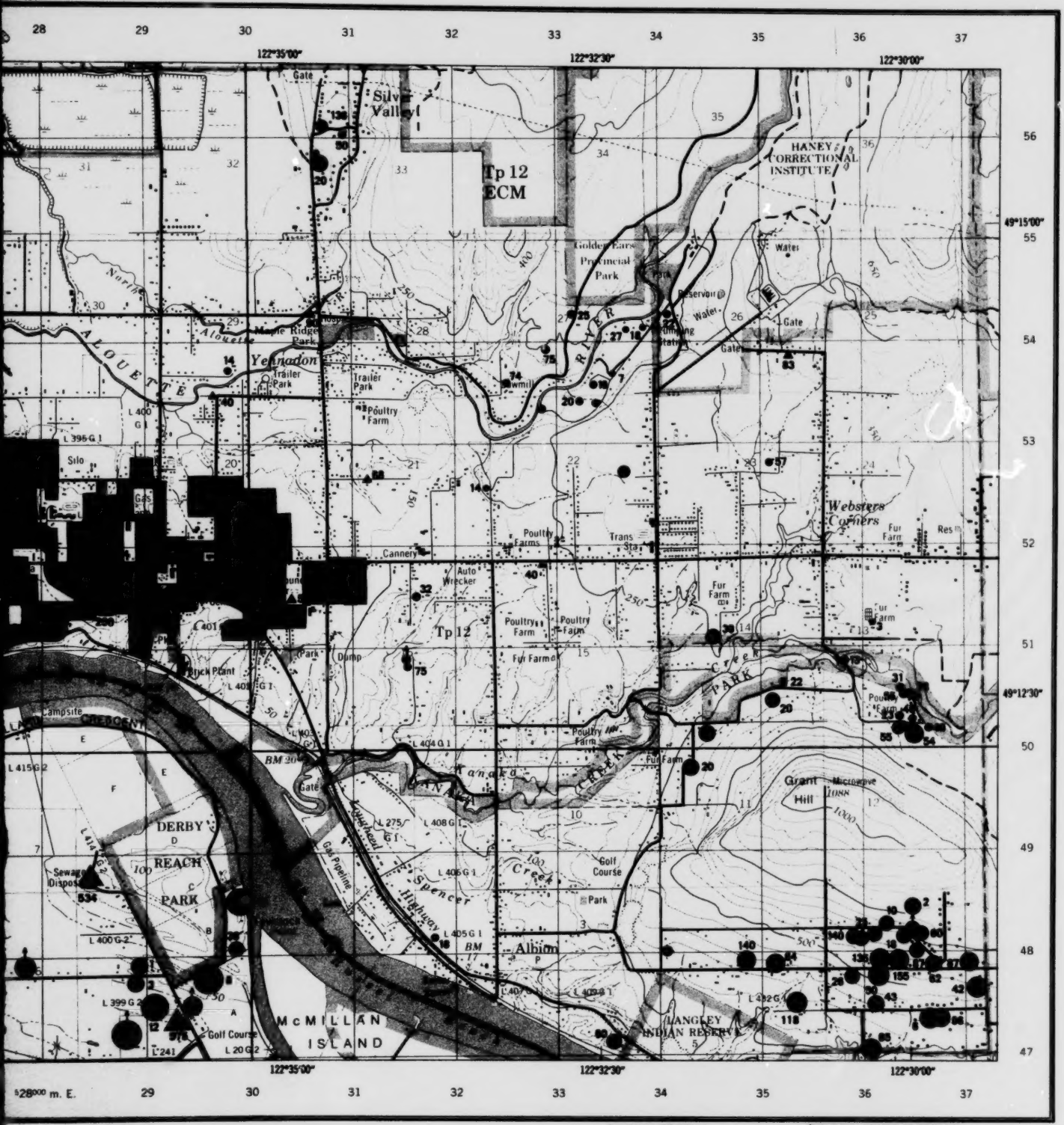
Compiled by E.C. Halstead, to accompany Report by E.C. Halstead, National Hydrology Research Institute, Inland Waters Directorate.

FIGURE 17. WELL LOCATIONS, TOWNSHIP 12, LANGLEY-MAPLE

FIGURE 17. EMPLACEMENT DES PUITS, CANTON 12, MUNICIPALITÉS DES



Compilation par E.C. Halstead.
pour accompagner le rapport de E.C. Halstead.
Institut national de recherche en hydrologie.
Direction générale des eaux intérieures.

ÉTABLIE PAR LA DIVISION DE DESSIN, SCE.
MINISTÈRE DE L'ENVIRONNEMENT, 1983

IMPRIMÉE PAR LA DIRECTION DES LEVÉS ET DE LA CARTOGRAPHIE.
MINISTÈRE DE L'ÉNERGIE, DES MINES ET DES RESSOURCES.

S, TOWNSHIP 12, LANGLEY-MAPLE RIDGE DISTRICT MUNICIPALITIES.
CANTON 12, MUNICIPALITÉS DES DISTRICTS DE LANGLEY ET DE MAPLE RIDGE.

Water from the Greater Vancouver Water District is distributed by pipeline throughout most of the township, except for the southeast quarter. In 1961, the Water District drilled eight test holes in search of ground water to increase the supplies. Six of the test holes ended in bedrock at less than 30 m, one intersected an aquifer between 5 and 11 m, and the other was drilled to a depth of 153 m, only to be abandoned as a dry hole.

In the southeast quarter, mainly the highland area including Grant Hill, water supplies are obtained from wells drilled to depths of 75 to 150 m, and completed in sandstone. Yields are in the order of 0.7 to 3 L/s. Below elevations of about 100 m, ground-water supplies are in places available at depths commonly less than 30 m at the contact of the overlying marine stony silty clays and the bedrock. Two wells in section 12, failing to find sufficient water at the marine clay/bedrock contact, continued into the sandstone to depths of 73 and 98 m. Both found ground water at that depth with chloride concentrations exceeding 1200 mg/L. Elsewhere, ground water within the sandstone is of better quality, with total dissolved solids averaging 120 mg/L, but all pH values are greater than 9.

Township 13

The greater part of township 13 lies within the Langley Upland. Surface elevations rise to more than 122 m in the Aberdeen area, and the uneven topography is attributed to modification by stagnant melting ice masses that accompanied the last glaciation. The Upland is bounded on the southeast by a hummocky morainal ridge that is dissected by meltwater channels. An outwash plain occupies the southeast corner. Figure 18 (in pocket) illustrates the distribution of the hydrostratigraphic units together with a well location map.

The hydrostratigraphy of the Langley Upland (Fig. 33), established as a result of drilling the Aldergrove test hole in 1964, consists of an aquifer of fluvial sand at an average base depth of 30 m and part of hydrostratigraphic unit A. This ubiquitous unit is the source of most domestic supplies on the upland and also yields ample supplies in several municipal wells (Table C-1, Wells Nos. 27 and 30). Underlying this aquifer and extending approximately to present sea level elevation is a thick stony clay, hydrostratigraphic unit B, that lies on a till. Below this till, a number of test holes have penetrated a confined aquifer of gravel and sand with ample yields for industrial and municipal use. Because of the high phosphate content, in the order of 2.5 mg/L, this productive aquifer is unsuitable for municipal supplies.

The morainal ridges with ice-contact gravel and sand (Fig. 19), together with the outwash plains in the southeast corner of the township, constitute important water table aquifers that yield adequate water for irrigation,

Figure 19. Ice-contact sand and gravel pit with an exposed water table.

industrial and municipal supplies (Table C-1, Wells Nos. 34, 35 and 36).

In the northeast quarter of the township, local flow systems within hydrostratigraphic unit A create outstanding artesian conditions in the discharge areas. For example, a well drilled 32 m in section 35 flows at a rate of more than 30 L/s to a height of 2.4 m above the land surface. Drilling in the recharge zones or on the topographic highs in the same area has not been as productive. Test holes in sections 22 and 23 have been drilled to depths of 205 and 188 m, respectively.

Township 14

A rolling upland surface, reaching elevations of more than 140 m south of the Fraser River, gives way to an area of approximately 11 km^2 adjacent to the river, with elevations less than 6 m above sea level. The walls surrounding the south side of Glen Valley rise to more than 90 m and are gullied. Nathan Creek and its tributaries drain the surrounding uplands northward into the Fraser River.

The upland area south of the Fraser River (Fig. 20 in pocket) is underlain by glaciomarine clays with interbedded glaciofluvial sediments representing hydrostratigraphic unit A. In places, the interbedded glaciofluvial sands are extensive and provide ample water supplies to wells commonly drilled to depths less than 40 m. For example, in section 4, a well drilled 32 m intersected an aquifer from 28 to 31 m, yielding 9 L/s for a community water system (Table C-1, Well No. 32).

In the southwest quarter of the township, ground water is commonly developed from interbedded glaciofluvial sand and gravel at depths ranging from 60 to 75 m. In the southeast quarter in the Mt. Lehman area, ice-contact gravel and sand with lenses of till extending from the surface to depths of 15 m provide a water table aquifer. However, north and west of Mt. Lehman test holes to depths ranging from 90 to 180 m have failed to find water of suitable quality. For example, a test hole drilled to a depth of 150 m in section 16 penetrated an aquifer, yielding water with more than 1800 mg/L total dissolved solids. Because aquifer materials are discontinuous and yield inadequate supplies of potable water, the greater part of this township is supplied with water brought by pipeline from production wells elsewhere in the municipality.

Glen Valley is underlain by a thick series of silty clays. Wells commonly intersect a till at an approximate depth of 140 m, below which a confined aquifer exists under flowing artesian conditions. Although the supply is adequate, chlorides and sulphates in the range of 700 and 300 mg/L, respectively, are too high for most domestic uses.

North of the Fraser River ground water is developed from bedrock, mainly sandstones. Wells are drilled to depths averaging 135 m and yields rarely exceed 0.4 L/s. The quality of ground water from the bedrock in some cases does not meet Canadian Drinking Water Standards (Table A-1, Appendix A) with respect to fluorides, and values commonly exceed the 1.5 mg/L acceptable limit. For example, the well at Ruskin Elementary School, drilled 130 m into sandstone, yields ground water with fluorides in the range of 2.2. mg/L.

Township 15

The northern part of township 15 (Fig. 21) is mountainous, with elevations reaching 600 m above sea level. Elsewhere the surface is rolling, with bedrock outcrops reaching prominent elevations of more than 350 m. Below an elevation of approximately 240 m, bedrock is covered by unconsolidated lodgment till with a sandy loam matrix. Below elevations of approximately 180 m, these tills are mantled by stony clays. The maximum thickness of these surficial deposits is probably not more than 45 m. Ground water is obtained where outwash gravel and sand occur below the till and at the contact with the bedrock. This aquifer is thin and discontinuous and, where found, yields low flow in the order of 0.4 L/s. Locally, within topographic basins, these aquifer materials are thicker, as indicated by drilling in the 10900 block, 272 St., where a well completed at a depth of 36.5 m penetrated an aquifer that produced 12.6 L/s (Table C-1, Well No. 27).

Where the surficial deposits are thin, or consist mainly of impermeable materials, wells and test holes are drilled into bedrock. In the southern part of the township, Tertiary sandstones, which yield ground water in volumes less than 0.4 L/s, are found; well depths vary from 30 to more than 180 m. The ground water obtained from the sandstones consistently yields fluorides ranging in concentration from 1.2 to 5.8 mg/L. Bedrock elsewhere includes volcanic, granitic and metamorphic rocks. Well depths are highly variable and ground water is produced only from fractures.

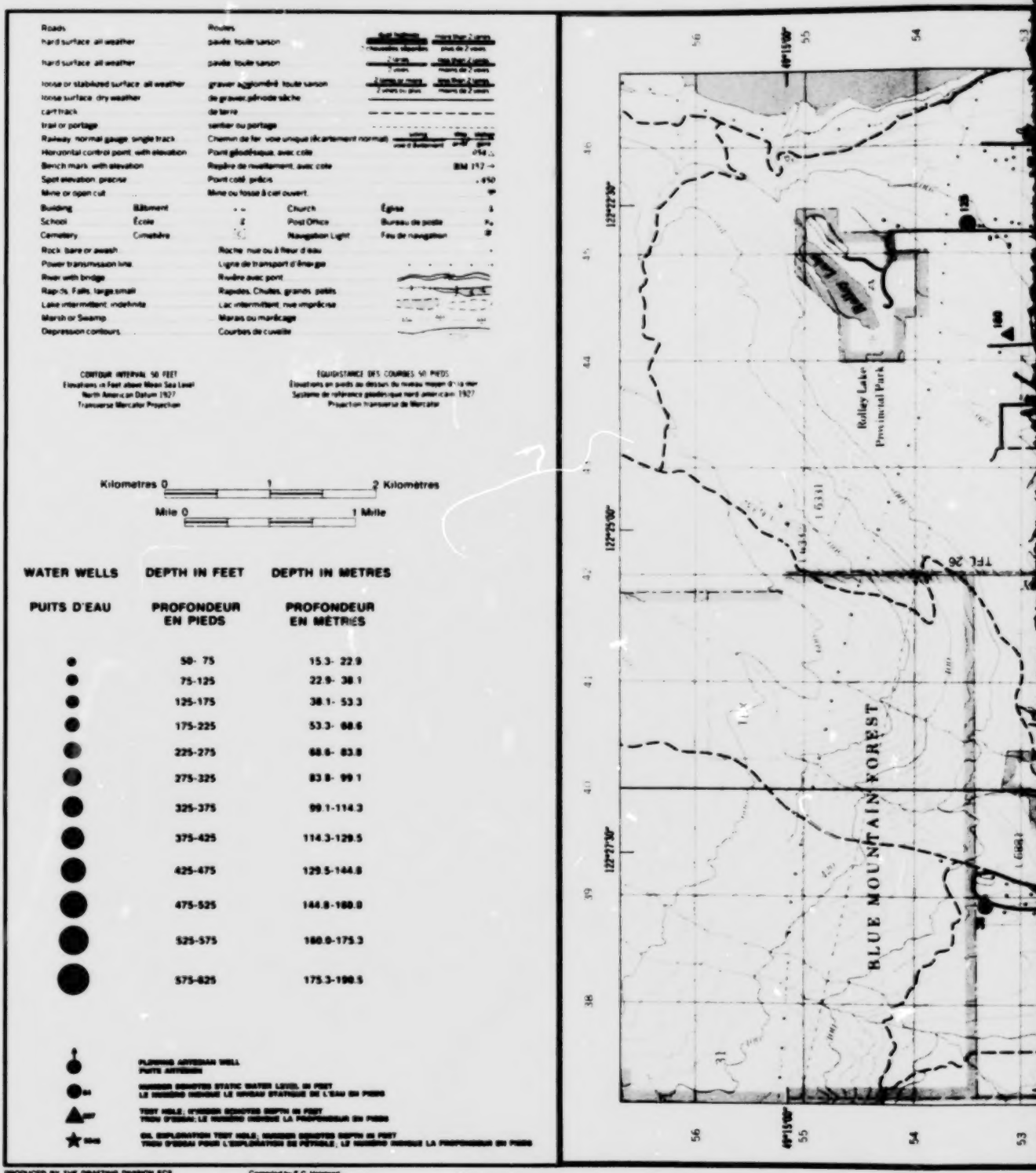


FIGURE 21. WELL LOCATIONS, TOWNSHIPS 14 AND 15,

FIGURE 21. EMPLACEMENT DES PUITS, CANTONS 14 ET 15,

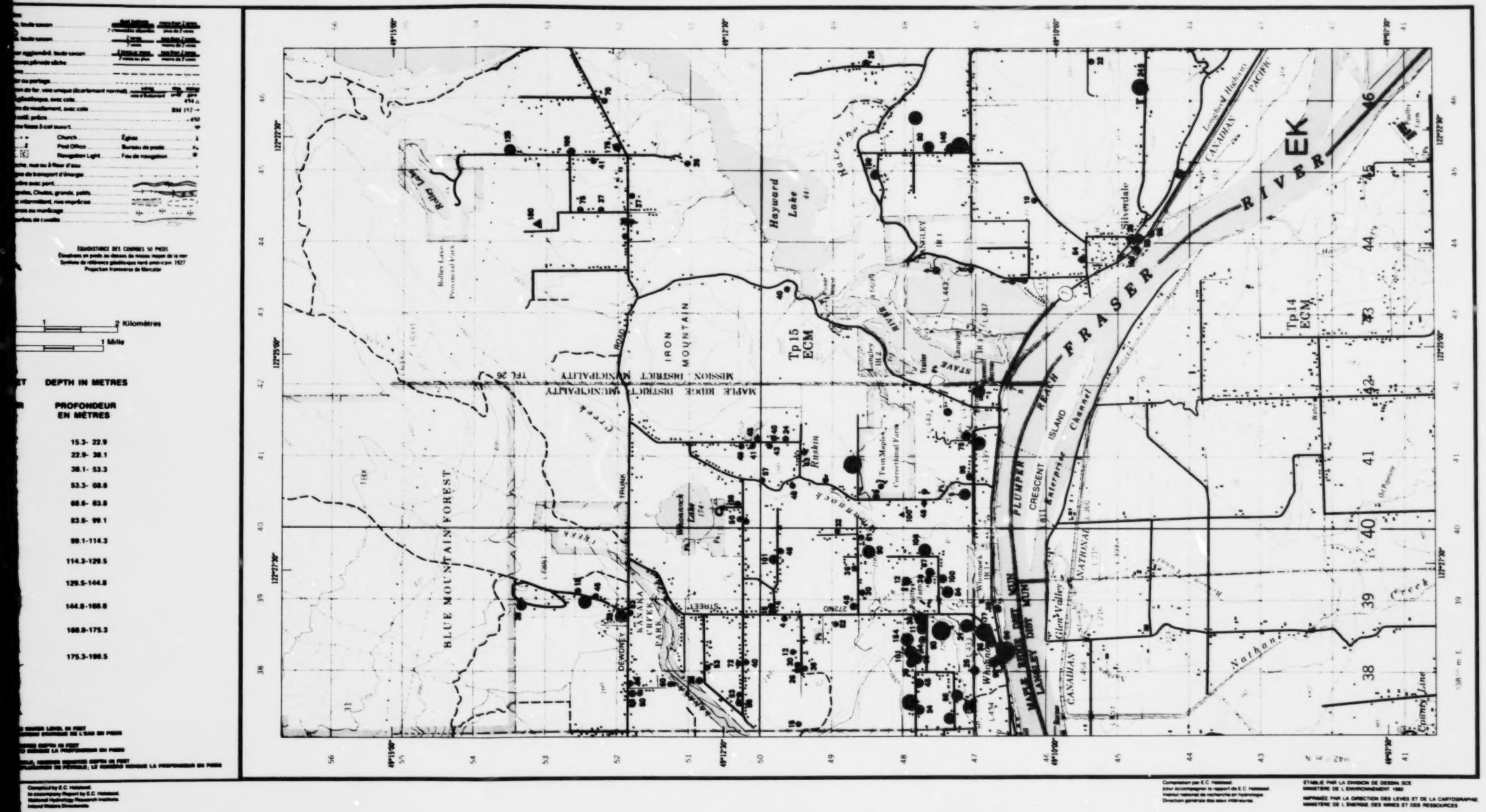


FIGURE 21. WELL LOCATIONS, TOWNSHIPS 14 AND 15, NORTH OF FRASER RIVER, MAPLE RIDGE AND MISSION DISTRICT MUNICIPALITIES.

FIGURE 21. EMPLACEMENT DES PUITS, CANTONS 14 ET 15, NORD DU FRASER, MUNICIPALITÉS DES DISTRICTS DE MAPLE RIDGE ET DE MISSION.

Township 16

Till, glaciofluvial, glaciolacustrine and ice-contact deposits left upon retreat of a valley glacier that advanced from the east and northeast into the Fraser Lowland during final stages of deglaciation (Armstrong, 1981) cover a large part of township 16 (Fig. 22, in pocket). These deposits, collectively termed Sumas Drift, are assigned to hydrostratigraphic unit C and constitute a water table aquifer (Fig. 23) that provides ground water to 14 production wells, a similar number of irrigation wells, industrial supplies for food processing plants as well as 130 L/s for a trout hatchery (Table C-1, Wells Nos. 36 to 46). Prior to the more recent ground-water developments, spring discharge from this aquifer was estimated at 263 L/s. Precipitation in the area provides recharge, and in those years with below normal rainfall, a significant decline in the water table is observed (Fig. 24). During the irrigation season, total ground-water withdrawal, including irrigation wells, municipal wells, industrial wells and the trout hatchery (domestic and farm wells not included) consume more than 4.1×10^7 m^3 a day.

In the northwest part of the township, the rolling upland is supplied with ground water brought in by pipeline but in some places, where piped water is not available, ground water is commonly recovered from interbedded sand and gravel within the thick succession of stony marine clays. For example, in the NW 1/4 section 30, 15 wells averaging 50-m depth and yielding good quality ground water were drilled in a subdivision.

Township 17

Township 17, south of the Fraser River (Fig. 25), lies within the Matsqui Prairie, which is a lowland with an average elevation 6 m above sea level and underlain by more than 180 m of silty clays. Drilling for water supplies has not been successful, but in an area northeast of Matsqui Village coarser textured floodplain and channel deposits yield adequate supplies to sandpoints and shallow dug domestic wells.

North of the Fraser River, township 17 occupies a large part of Mission District Municipality. Surface water from Cannell Lake is brought by pipeline to supply most of the area. Although Sumas Drift deposits are extensive over the municipality, in most places they are too thin to provide suitable aquifers, so that most wells are completed in bedrock. The bedrock surface is channeled and irregular. Test holes drilled in sections 27 and 28 penetrated as much as 60 m of unconsolidated materials that were not suitable for ground-water exploitation, whereas in section 19 a channel filled with sand and gravel yields ample water to wells drilled up to 60 m.

Figure 23. Water table exposed in gravel pits, Section 7, Township 16, Matsqui District Municipality.

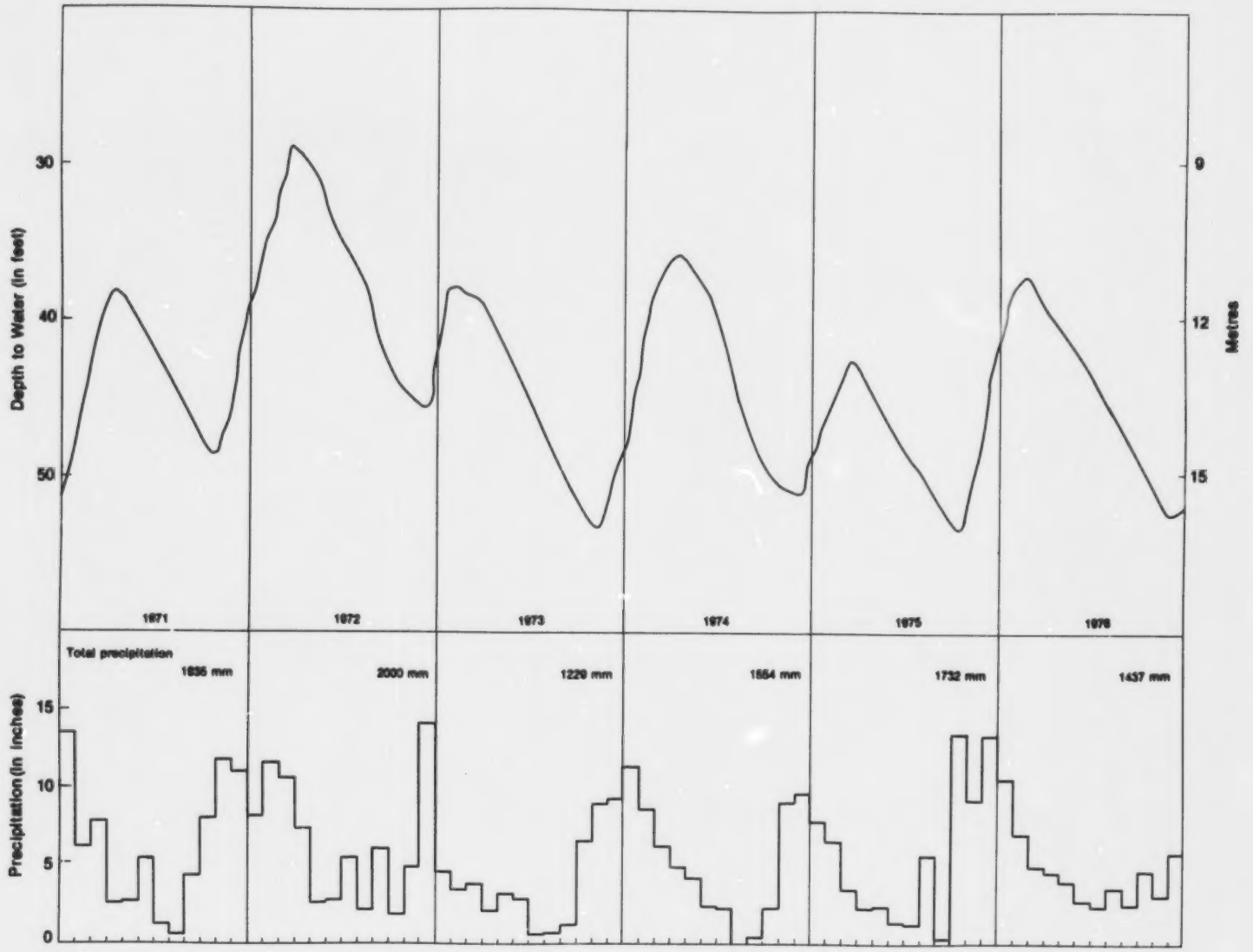
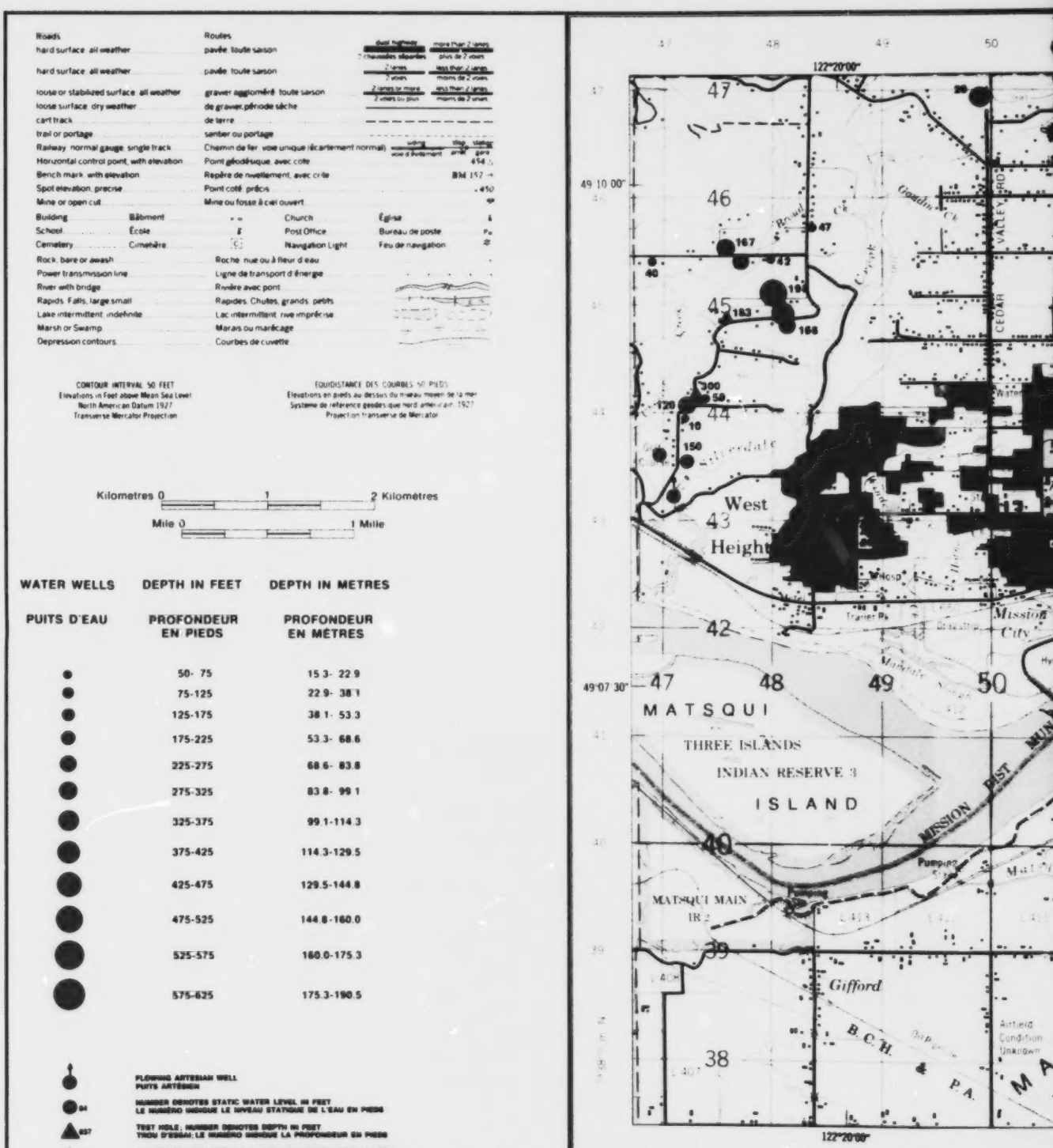


Figure 24. Hydrographs, Clearbrook Municipal Well Fields.



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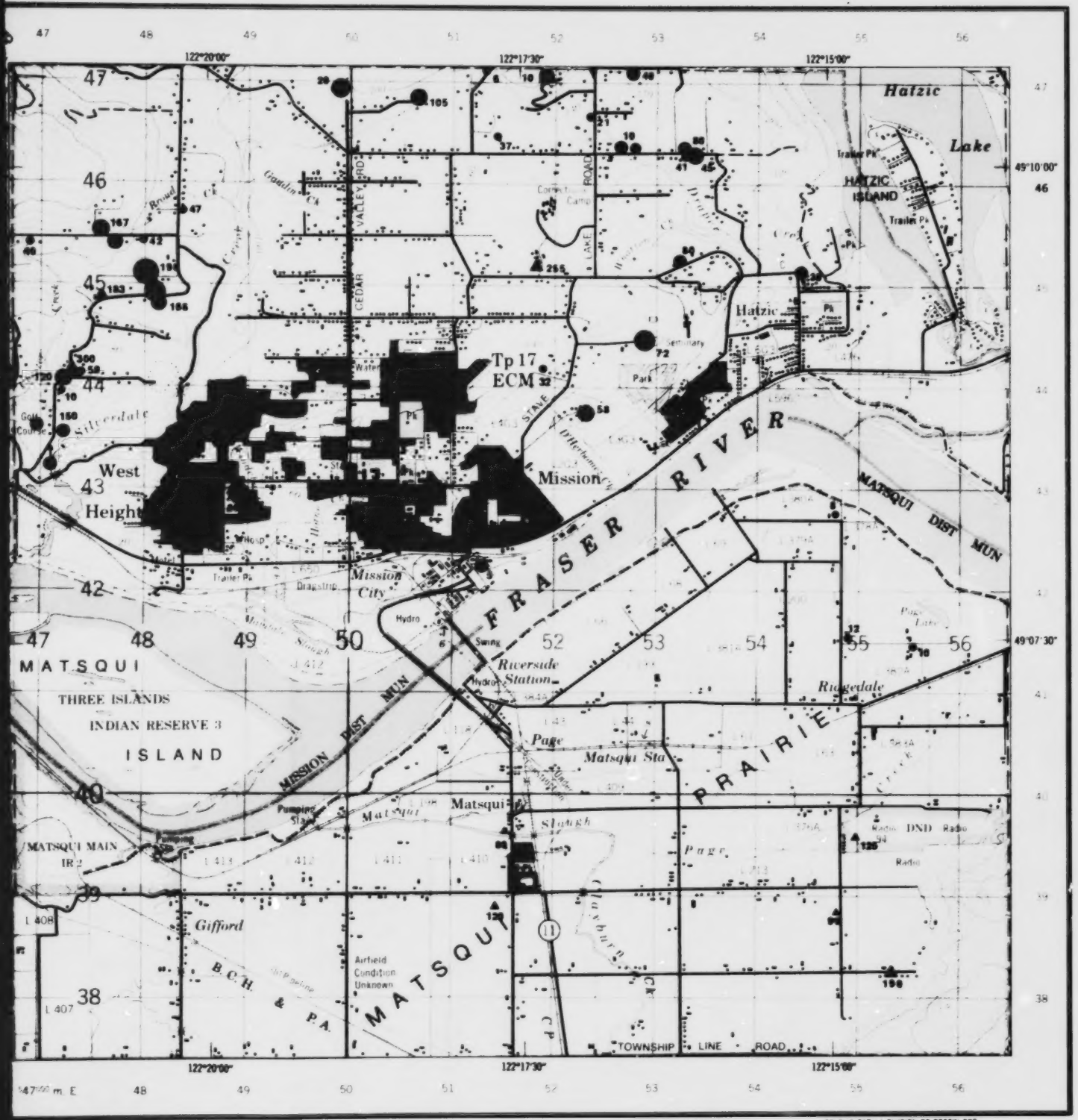
to accompany Report by E.C. Halstead
National Hydrology Research Institute
Inland Waters Directorate

FIGURE 25. WELL LOCATIONS, TOWNSHIP 17, MATSQUI AND M

FIGURE 25. EMPLACEMENT DES PUITS, CANTON 17, MUNICIPALITÉS DE



Compilation par E.C. Halstead
pour accompagner le rapport de E.C. Halstead
Institut national de recherche en hydrologie
Direction générale des eaux intérieures

ETABLIE PAR LA DIVISION DE DESSIN SCE
MINISTÈRE DE L'ENVIRONNEMENT 1983

IMPRIMÉE PAR LA DIRECTION DES LEVÉS ET DE LA CARTOGRAPHIE
MINISTÈRE DE L'ÉNERGIE DES MINES ET DES RESSOURCES

NS, TOWNSHIP 17, MATSQUI AND MISSION DISTRICT MUNICIPALITIES.
TS, CANTON 17, MUNICIPALITÉS DES DISTRICTS DE MATSQUI ET DE MISSION.

Coarse-textured Fraser River floodplain deposits in Hatzic Prairie Region yield good quality water to wells drilled up to 25 m. A test well drilled in the floodplain deposits in NE 1/4 section 16 penetrated more than 48 m of interbedded fine to coarse sand, silt and clay that yielded 30 L/s during a 72-h test (Table C-1, Well No. 47).

Township 18

Township 18 (Fig. 26) is mountainous except for Hatzic Valley, which occupies the eastern border of the township. The northern half of this valley is underlain by glaciomarine stony silts up to 100 m thick, and the southern half is underlain by floodplain sand and gravel up to 60 m thick. In sections 25 and 36 a number of successful wells have been completed at depths ranging from 50 to 60 m. At this depth, an aquifer of sand and gravel is found that yields good quality water with total dissolved solids commonly less than 80 mg/L. In the southern part of the valley, wells are completed in the floodplain deposits and range in depth from 25 to 30 m. However, one well completed at a depth of 94 m in section 12 penetrated silty clays and found ground water, under flowing artesian pressures, that contained chlorides in the range of 850 mg/L.

Throughout the rest of the township, the mountainous terrain is covered by a thin veneer of unconsolidated deposits below elevations of 300 m. All wells are drilled into bedrock except in sections 21 and 22 within the Cardinal Creek Valley, where wells have penetrated as much as 76 m of ice-contact gravel and sand.

Township 19

Sumas Mountain, rising to elevations of more than 380 m, occupies the northwest third of the township (Fig. 27). Elsewhere, including a large part of Sumas Prairie, elevations are less than 6 m. The total thickness of surficial deposits filling the valley is unknown, and the deepest test holes have reached only to depths of 180 m intersecting silty clays. In 1924, a shallow lake occupying part of Sumas Prairie was artificially drained, exposing terraced beached sands around its perimeter. These sands now produce water from shallow wells. Elsewhere, water is distributed by pipelines from production wells in township 16 (Table C-1, Wells Nos. 44 and 45).

Drilling for water supplies on Sumas Mountain has not been too successful and all wells penetrate bedrock. Yields are low and wells have been drilled to depths greater than 150 m. A test hole drilled at Kilgard Indian Reserve to a depth of 90 m initially produced 2.5 L/s, but within a few months the yield was negligible after having depleted the water stored in a fracture zone. A second well, drilled in 1973 to a depth of 90 m into a bedrock fracture zone, was test pumped for 3 h at 2 L/s, and the water in storage could not recharge at the pumping rate. A successful well was finally completed in 1977, on the Kilgard Indian Reserve, in surficial materials deposited as a fan at the base of the mountain. The well was finished at a depth of 13 m, with a 60-slot screen and produced 5 L/s.

Township 22

Vedder Mountain, rising to elevations more than 900 m, occupies a large part of township 22 (Fig. 28) and separates the northeast corner, which is part of Sumas Prairie from the Cultus Lake-Columbia Valley recreational and farming district in the southeast part of the township.

Columbia Valley is an intermontane valley occupying approximately 15.5 km^2, with elevations ranging from 43 m at Cultus Lake to more than 213 m. The valley is underlain by an irregular bedrock surface, and well logs indicate that in places more than 105 m of poorly sorted gravel, sand and till lenses are found. The wells all yield ample supplies of good quality water, with total dissolved solids about 150 mg/L, whether completed in the surficial deposits or in the bedrock. Static water levels are commonly more than 30 m below ground level. Discharge of ground water from Columbia Valley is most likely into Cultus Lake.

Drainage from Cultus Lake is controlled via Sweltzer Creek, to maintain lake levels. A test hole drilled for a Fisheries Research Station in section 36 near the river penetrated 26.7 m of unconsolidated material overlying bedrock, but only the bottom 2 m consisted of aquifer material.

The northeast corner of the township lies in Sumas Prairie and includes the Yarrow residential area. Floodplain gravel and sand up to 10 m deposited by Chilliwack River provides limited ground water to shallow wells and sandpoints but, for most of the area, prospecting for ground water has not been successful. A test hole drilled in 1958 penetrated 120 m of silty clays without finding any permeable material. In 1979, three test holes were completed to depths of 39.5 m, 27.0 m and 36.5 m, but the materials penetrated were too fine to be developed for municipal water supplies.

Residential properties, mainly in section 29 in the Majuba Hill area, obtain water supplies from wells drilled into the bedrock to depths up to 60 m.

Township 23

Township 23 occupies part of the floodplain area that extends northeast from Sumas Prairie. Vedder River crosses sections 1 to 5 and flows into the Vedder Canal, which joins Sumas River in township 20. Chilliwack Mountain rises to elevations of more than 365 m in section 27, but elsewhere the surface is generally flat (Fig. 29).

Floodplain gravel and sand up to 45 m thick covers a large part of the southern half of the township. These permeable materials provide a water table aquifer from which ground water has been developed for production wells to supply the Canadian Forces Base at Sardis and also the Elk Creek Water Works serving Chilliwack Municipality (Table C-1, Wells Nos. 50 and 51). One production well, 30 m in depth, was pumped at rates of 126 L/s. In section 11, a production well 16 m deep supplies a food processing plant. Elsewhere, except on Chilliwack Mountain, silty sand and clay, mainly floodplain sediments of the Fraser River, are sources of good quality ground water recovered from shallow bored wells and more commonly by sandpoints up to 22 m deep.

Residential development on Chilliwack Mountain requires drilling for supplies into bedrock. Wells are commonly 75 m deep but yields are very low, approximately 0.1 L/s. A 104-m deep well, on a small terrace adjacent to the Fraser River, intersected a fracture zone within the bedrock from which water is discharged under flowing artesian pressures.

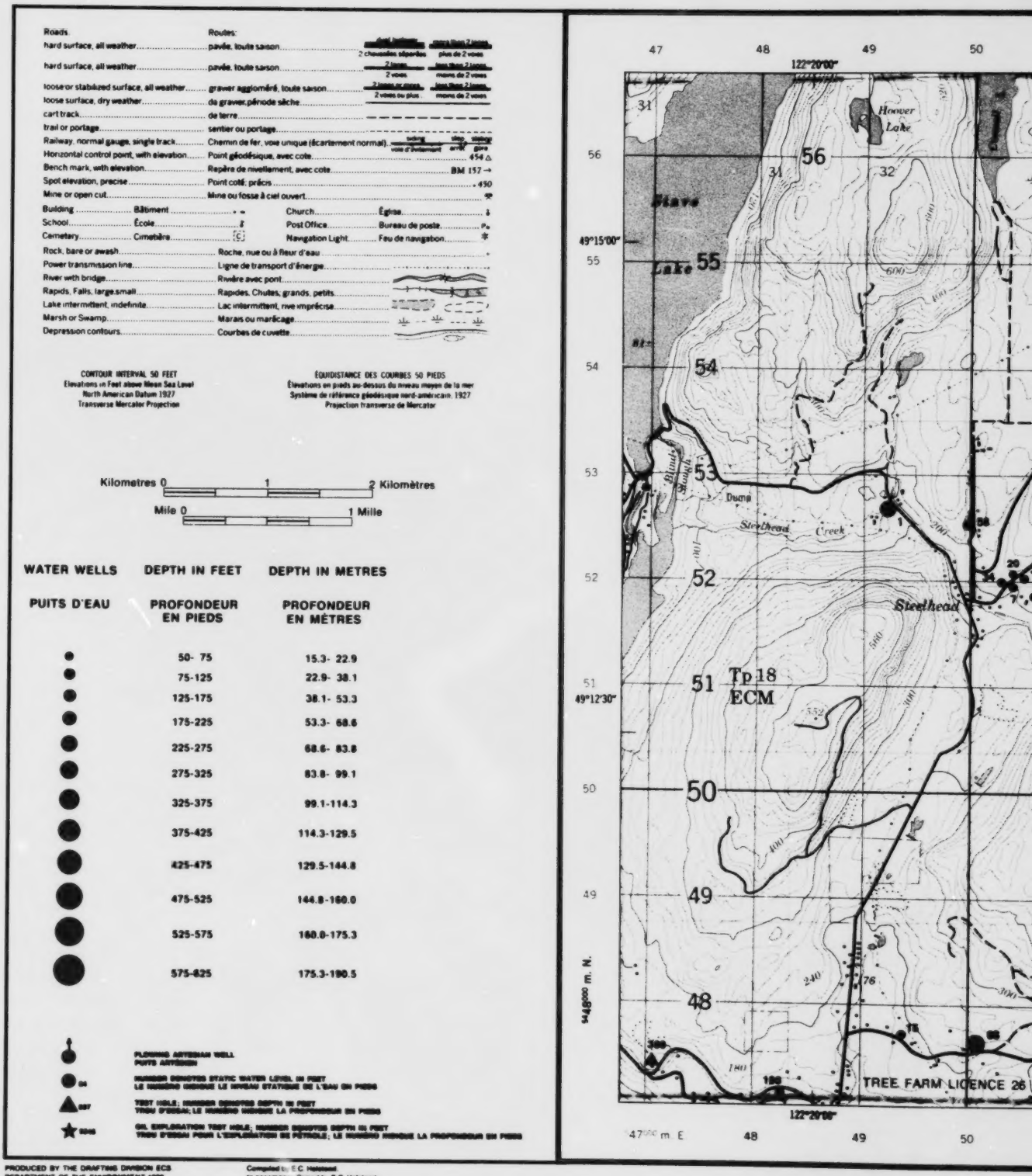
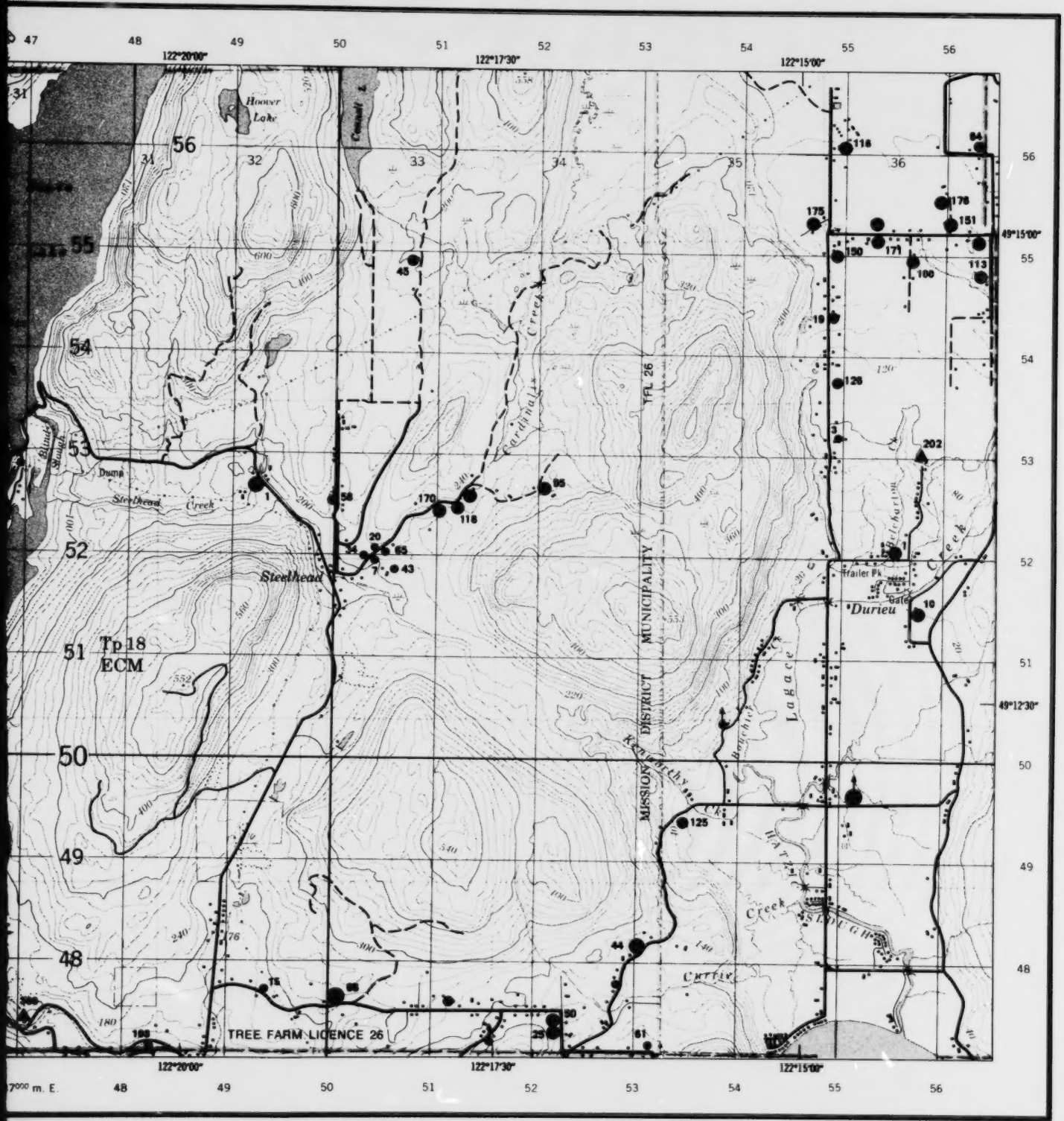


FIGURE 26. WELL LOCATIONS, TOWNSHIP 18, MISSION

FIGURE 26. EMPLACEMENT DES PUITS, CANTON 18, MUNICIP



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OCATIONS, TOWNSHIP 18, MISSION DISTRICT MUNICIPALITY.
T DES PUITS, CANTON 18, MUNICIPALITÉ DU DISTRICT DE MISSION.

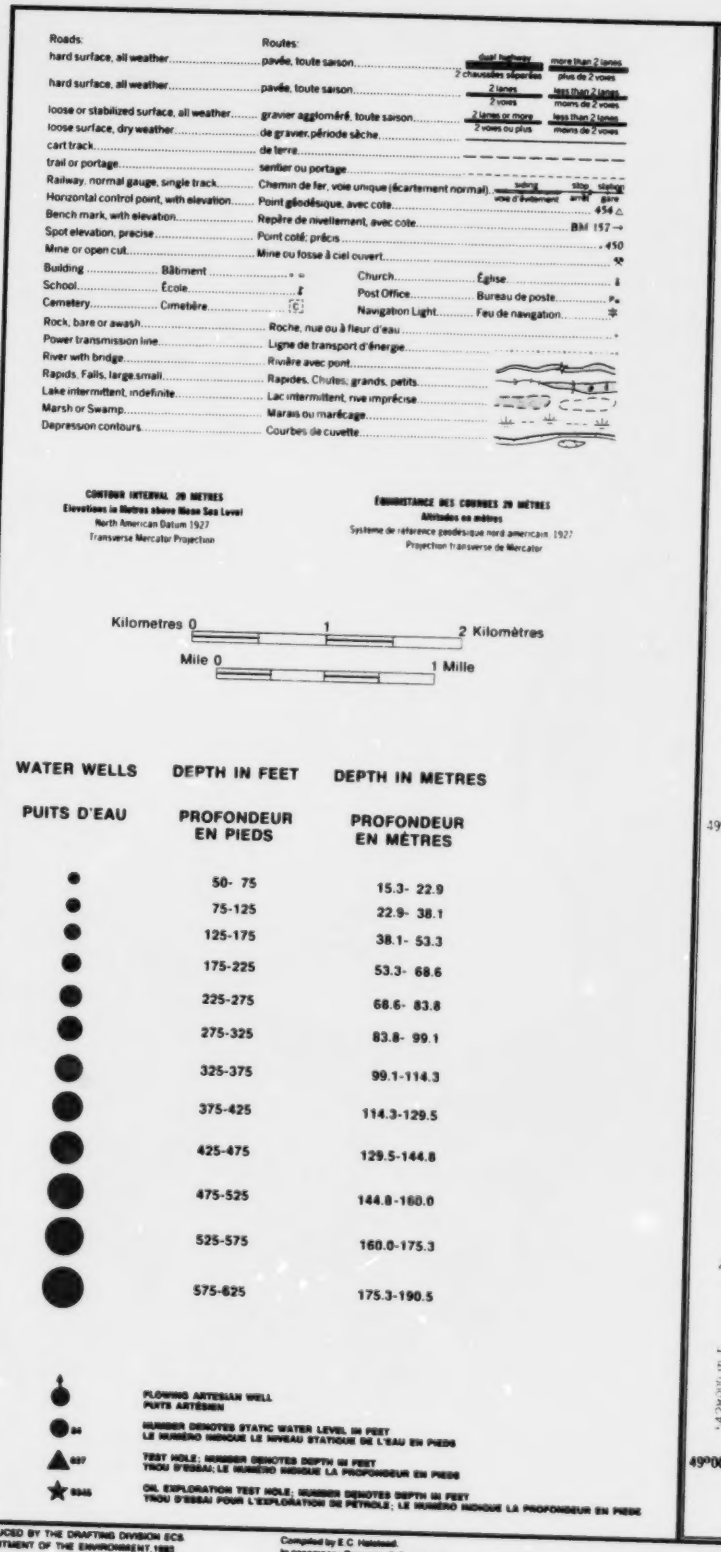
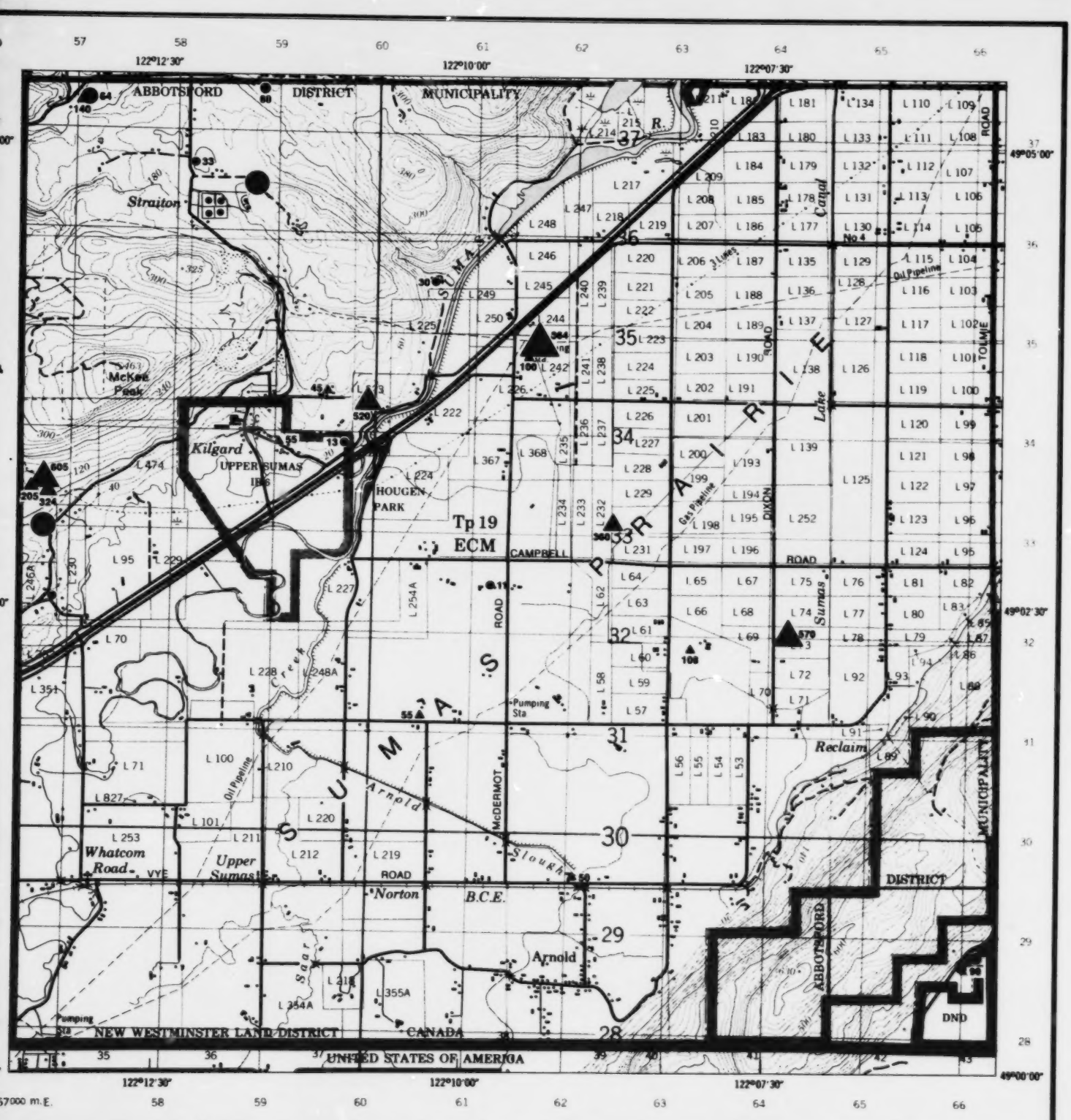


FIGURE 27. WELL LOCATIONS, TOWNSHIP 19, ABBOTSFORD

FIGURE 27. EMPLACEMENT DES PUITS, CANTON 19, MUNICIPALITÉ



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CATIONS, TOWNSHIP 19, ABBOTSFORD DISTRICT MUNICIPALITY.
DES PUITS, CANTON 19, MUNICIPALITÉ DU DISTRICT D'ABBOTSFORD.

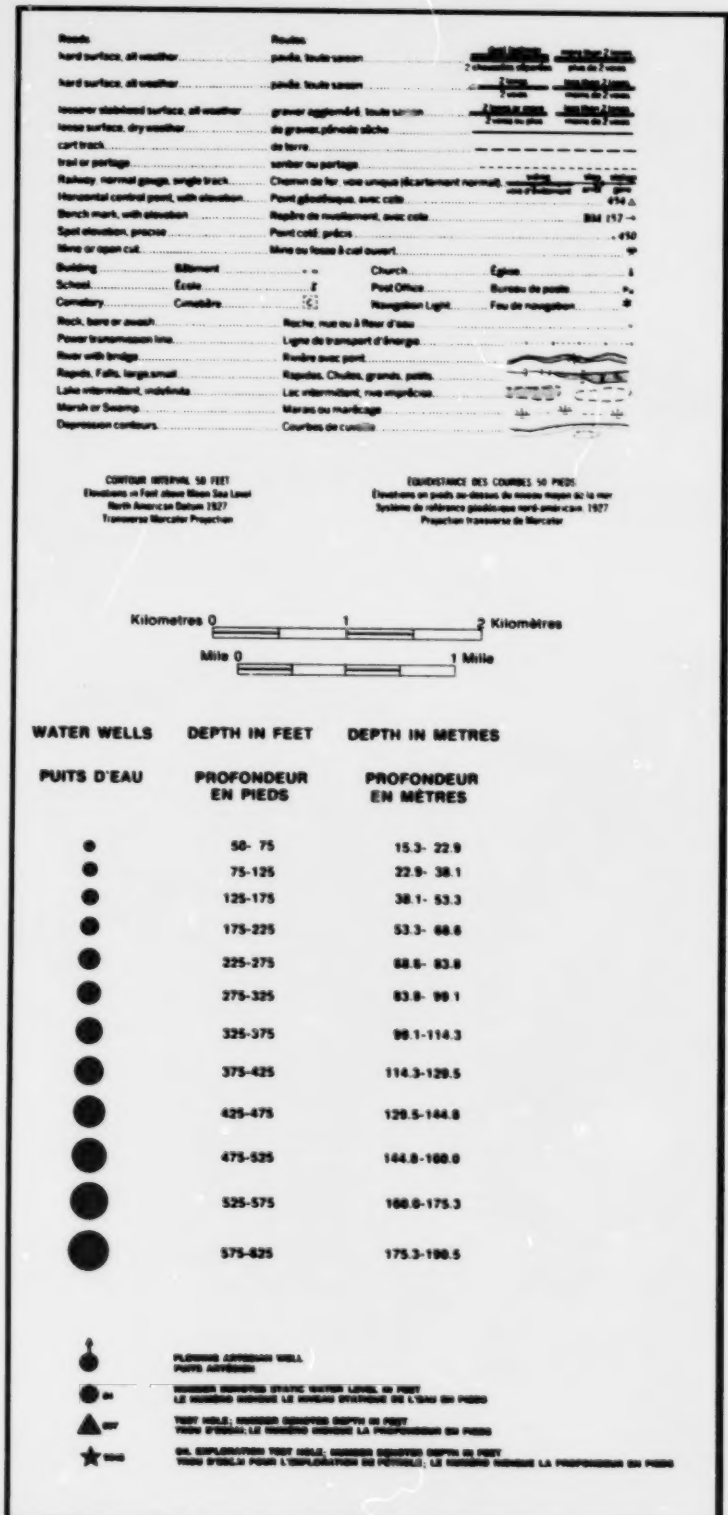

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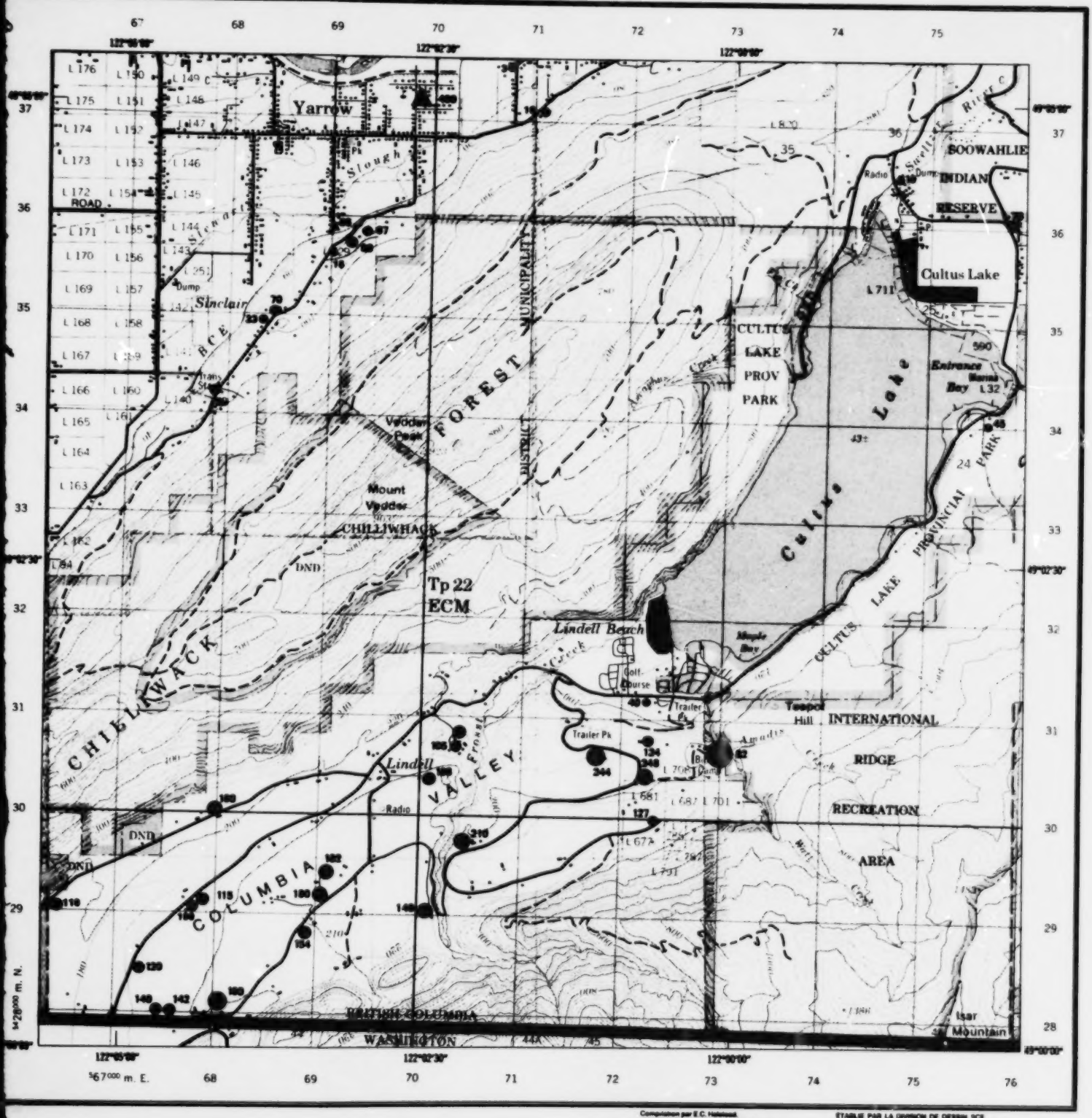
FIGURE 28. WELL LOCATIONS, TOWNSHIP 22, ABBOTSFORD AND CHI

FIGURE 28. EMPLACEMENT DES PUITS, CANTON 22, MUNICIPALITÉS DES DIST



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…S, TOWNSHIP 22, ABBOTSFORD AND CHILLIWACK DISTRICT MUNICIPALITIES.
…TS, CANTON 22, MUNICIPALITÉS DES DISTRICTS D'ABBOTSFORD ET DE CHILLIWACK.

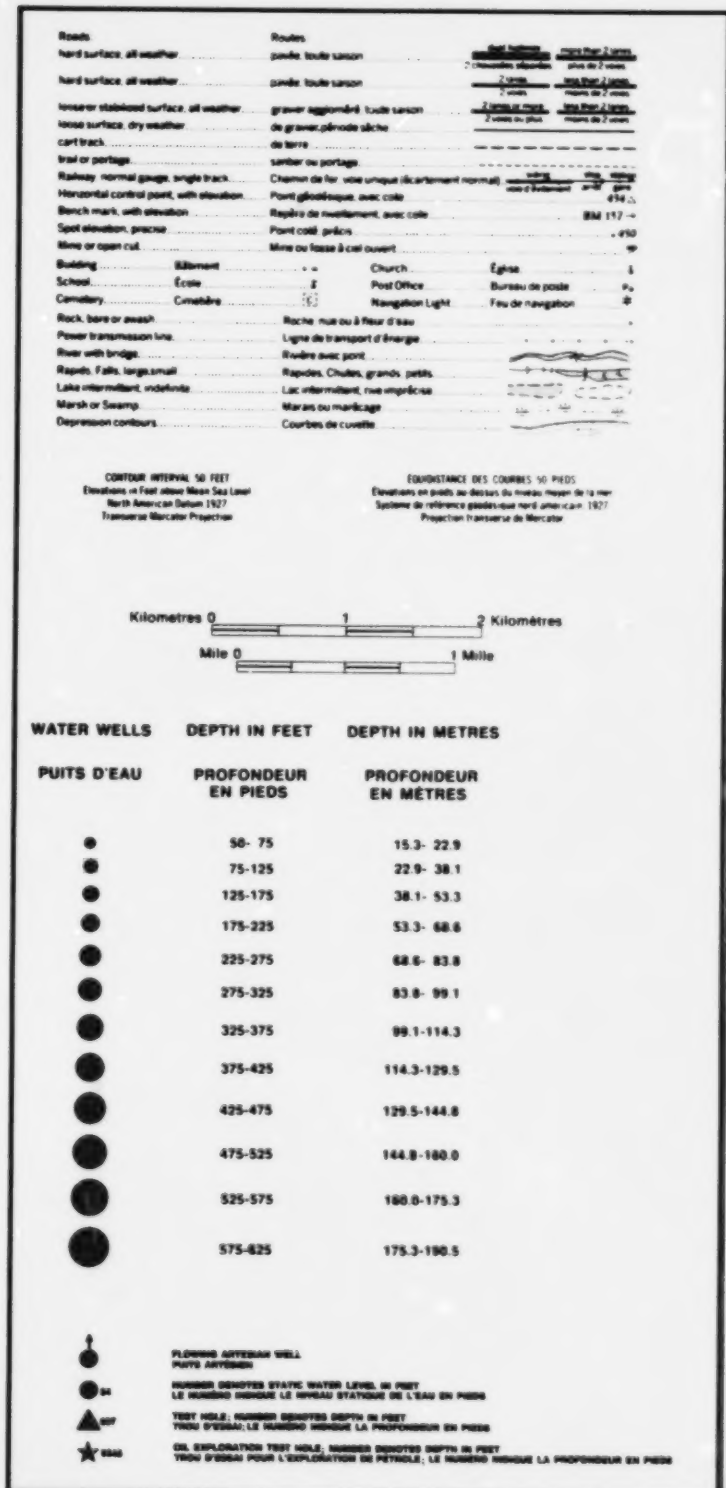

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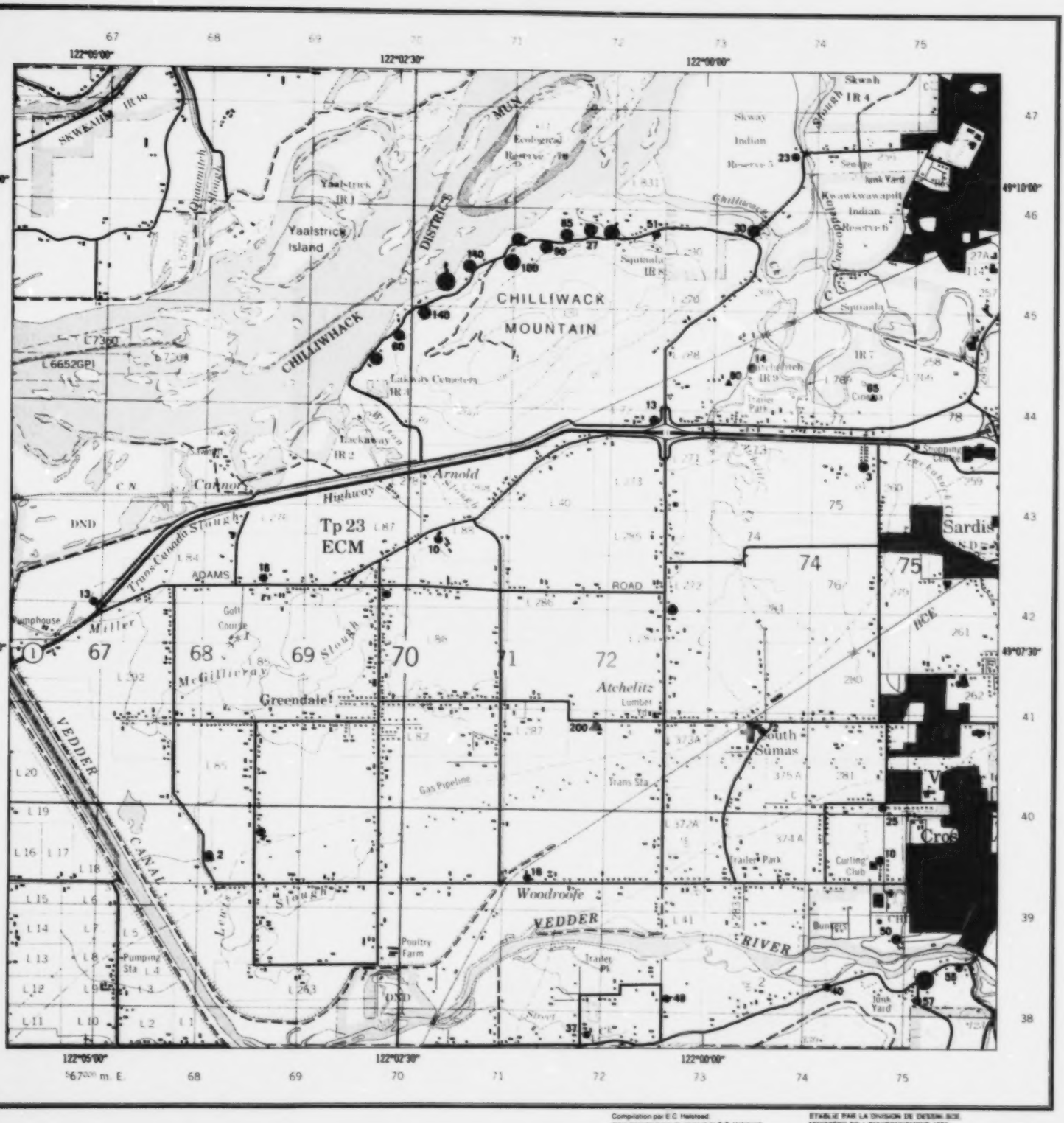
FIGURE 29. WELL LOCATIONS, TOWNSHIP 23, CHILLIWA

FIGURE 29. EMPLACEMENT DES PUITS, CANTON 23, MUNICIPA



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L LOCATIONS, TOWNSHIP 23, CHILLIWACK DISTRICT MUNICIPALITY.

ENT DES PUITS, CANTON 23, MUNICIPALITÉ DU DISTRICT DE CHILLIWACK.

Ryder Lake–Promontory Heights

The Ryder Lake–Promontory Heights district is an upland of about 23 km^2 on the west end of Skagit Range in the Cascade Mountains. Much of the district is mountainous and elevations range from 150 to 450 m. Chilliwack Valley bounds the district on the north, and its southern boundary is the Chilliwack River Valley. The eastern boundary is roughly the 450-m contour that curves around Lookout Ridge. The district is largely farm land, but it is gradually being subdivided into residential properties to take advantage of the commanding view at these elevations.

Four creeks—Midgley, Ryder, Wingfield, Young—drain the upland district into the Chilliwack River Valley, but the total estimated discharge of these four creeks is less than 280 L/s during the drier summer months.

The district is underlain by a thick succession of clastic sedimentary rocks consisting largely of highly deformed dark grey argillites with minor siltstone and fine-grained sandstone (Monger, 1969). Ground-water movement through the bedrock is limited to a system of secondary joints and fractures. With the exception of Mt. Tom, the bedrock surface is covered with unconsolidated materials that range in thickness from 1 m to more than 150 m. In places a thin deposit of windblown sand overlies the drift deposits left after the melting of the last glacial ice that occupied the area about 11 000 years ago. The drift consists of till commonly less than 1 m thick overlying a section of sand and gravel that, where exposed, may range up to more than 150 m in thickness. At the base, in some sections, a laminated clay is exposed.

Throughout most of the area, especially where the unconsolidated deposits are less than 3 m, wide diameter wells are dug to maximize storage, but even so, ground-water supplies are commonly exhausted by the end of summer. In some areas along the base of Lookout Ridge, as at the school and fire hall, springs provide adequate quantites of water.

The location of drilled wells and test holes is shown in Figure 30. Even though they extend to depths of more than 130 m, the test holes that penetrate the underlying sands and gravels have not always been successful in obtaining adequate water supplies. Similarly in other places, drilling in bedrock has failed to intersect water-bearing fractures.

Two water districts have been established; one at Promontory Heights services 19 lots by water from the Eden Bank Springs. The exploitation of water from these springs amounts to 8.3×10^2 m^3 a year per lot plus a quota of 2.5×10^3 m^3 a year for a slaughterhouse operation. The springs, at the east end of Russell Road, are located at the contact of the sand and gravel with the underlying laminated clays at an elevation of 45 m. Total discharge of the springs has not been estimated, but the quantity seems adequate for the present users.

The Southside Water District in section 4 obtains water from contact springs for a limited number of dwellings. These springs are not well exposed and the total discharge has not been estimated, but all available ground water is exploited.

Kent District Municipality

Much of Kent District Municipality is mountainous (Fig. 31), but a considerable area of agricultural land extends from the Fraser River to Harrison Lake. Elevations within this low-lying area are less than 20 m above sea level, and prior to dyking, the land was inundated by water during floods of the Fraser River. As a result, the surficial deposits are channel and floodplain deposits consisting of sandy and silty clay loams up to 4 m thick. These loams are underlain by sands and gravels that extend to an average depth of 36 m, below which clays and stony clays extend to bedrock. The thickness of these unconsolidated deposits is considerable in the channel of the Harrison River, as indicated by test holes drilled 147 m at Harrison Hot Springs, 130 m at Chehalis Indian Reserve and 172 m at Harrison Mills. At 92 to 100 m the test hole at Harrison Mills intersected a till deposit, but elsewhere till has not been found.

The sands and gravels underlying the channel and floodplain deposits are saturated and provide a water table aquifer for wells. Installations are usually within 15 m of the surface, as the water table is generally 3 m below the surface. The water table is responsive to precipitation and Fraser River flooding. Considerable volumes of ground water are available in the sands and gravels, but the quality is objectionable due to excessive dissolved iron and manganese.

During the period from June 1952 to June 1954, a study was undertaken by the Prairie Farm Rehabilitation Administration for a flood control storage development on Harrison Lake. The study, using 18 piezometers, five privately owned wells, four stream gauges and two monitored drainage ditches, provided 29 control points to monitor water table fluctuations. Figure 32 shows profiles of the water table in two sections through the Agassiz area. The study revealed the existence of a water table ridge elongated east to west, almost parallel with the railway

line, with ground water flowing north from the ridge and south to southwest to the Fraser River throughout most of the year. During periods of flooding in the Fraser River, ground water in the ridge is recharged by flood water and moves toward the north and west as shown on the profile of July 10, 1954, Figure 32. The water table also showed a response to the November 1954 precipitation.

At the southern end of Harrison Lake, hot springs with temperatures in a range of 60°C to 63°C are not related to any local ground-water flow systems within the Fraser Lowland but rather issue from fault zones within Tertiary intrusive rocks or from basement rocks adjacent to the intrusives along the Lillooet Valley fault system (Clark *et al.*, 1982). This fault system has apparently provided the fracture permeability required for deep circulation of precipitation and snowmelt within the area.

A test hole was completed to a depth of 130 m at a proposed site for a fish hatchery adjacent to the Chehalis River. Three production wells were then completed within the top 35 m of permeable deposits with an estimated safe yield of 456 L/s for the well field (Table C-1, Well No. 53).

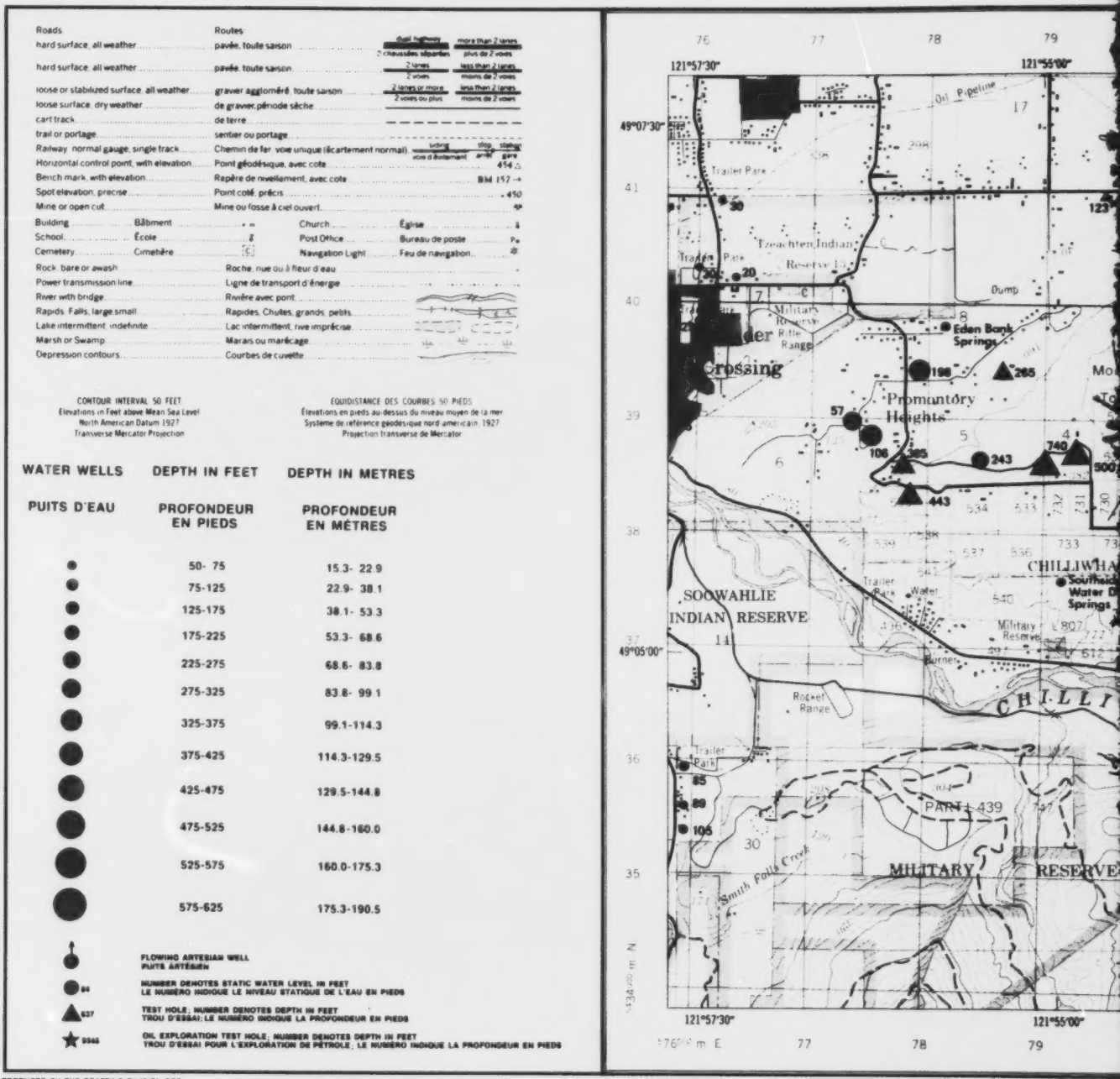

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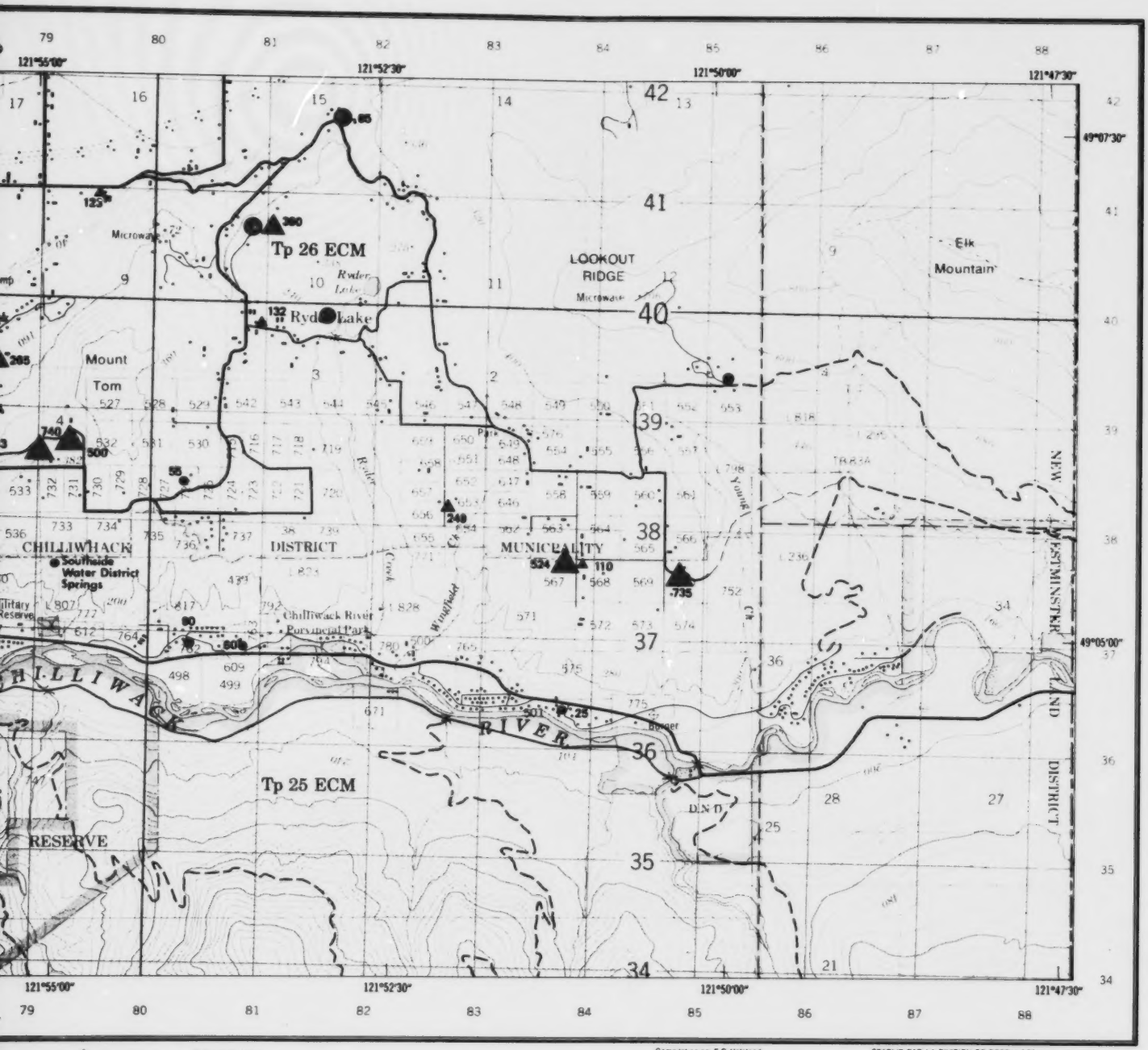
FIGURE 30. WELL LOCATIONS, RYDER LAKE – PROMONTORY

FIGURE 30. EMPLACEMENT DES PUITS, DISTRICTS DE RYDER LAKE – P



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ONTORY HEIGHTS DISTRICT, CHILLIWACK DISTRICT MUNICIPALITY.

LAKE – PROMONTORY HEIGHTS, MUNICIPALITÉ DU DISTRICT DE CHILLIWACK.

Roads	Routes		
hard surface, all weather	pavée, toute saison	2 chaussées séparées	plus de 2 voies
hard surface, all weather	pavée, toute saison	2 voies	moins de 2 voies
loose or stabilized surface, all weather	gravier aggloméré, toute saison	2 voies ou plus	moins de 2 voies
loose surface, dry weather	de gravier, période sèche		
cart track	de terre		
trail or portage	sentier ou portage		
Railway, normal gauge, single track	Chemin de fer, voie unique (écartement normal)	voie double	voie simple
Horizontal control point, with elevation	Point géodésique, avec cote		454 △
Bench mark, with elevation	Repère de nivellement, avec cote		BM 157 →
Spot elevation, precise	Point coté précis		• 450
Mine or open cut	Mine ou fosse à ciel ouvert		
Building / Bâtiment	Church / Église		
School / École	Post Office / Bureau de poste		
Cemetery / Cimetière	Navigation Light / Feu de navigation		
Rock, bare or awash	Roche, nue ou à fleur d'eau		
Power transmission line	Ligne de transport d'énergie		
River with bridge	Rivière avec pont		
Rapids, Falls, large, small	Rapides, Chutes, grands, petits		
Lake intermittent, indefinite	Lac intermittent, rive imprécise		
Marsh or Swamp	Marais ou marécage		
Depression contours	Courbes de cuvette		

CONTOUR INTERVAL 50 FEET
Elevations in Feet above Mean Sea Level
North American Datum 1927
Transverse Mercator Projection

EQUIDISTANCE DES COURBES 50 PIEDS
Élévations en pieds au-dessus du niveau moyen de la mer
Système de référence géodésique nord-américain 1927
Projection transverse de Mercator

Kilometres 0 1 2 Kilometres

Mile 0 1 Mille

WATER WELLS / PUITS D'EAU	DEPTH IN FEET / PROFONDEUR EN PIEDS	DEPTH IN METRES / PROFONDEUR EN MÈTRES
●	50- 75	15.3- 22.9
●	75-125	22.9- 38.1
●	125-175	38.1- 53.3
●	175-225	53.3- 68.6
●	225-275	68.6- 83.8
●	275-325	83.8- 99.1
●	325-375	99.1-114.3
●	375-425	114.3-129.5
●	425-475	129.5-144.8
●	475-525	144.8-160.0
●	525-575	160.0-175.3
●	575-625	175.3-190.5

FLOWING ARTESIAN WELL
PUITS ARTÉSIEN

84 NUMBER DENOTES STATIC WATER LEVEL IN FEET
LE NUMÉRO INDIQUE LE NIVEAU STATIQUE DE L'EAU EN PIEDS

937 TEST HOLE; NUMBER DENOTES DEPTH IN FEET
TROU D'ESSAI; LE NUMÉRO INDIQUE LA PROFONDEUR EN PIEDS

9545 OIL EXPLORATION TEST HOLE; NUMBER DENOTES DEPTH IN FEET
TROU D'ESSAI POUR L'EXPLORATION DE PÉTROLE; LE NUMÉRO INDIQUE LA PROFONDEUR EN PIEDS

3P PIEZOMETER : NUMBER AND LOCATION ALONG SECTION LINES N-S AND E-W
PIÉZOMÈTRE: NUMÉRO ET EMPLACEMENT LE LONG DES SECTIONS N-S ET E-W

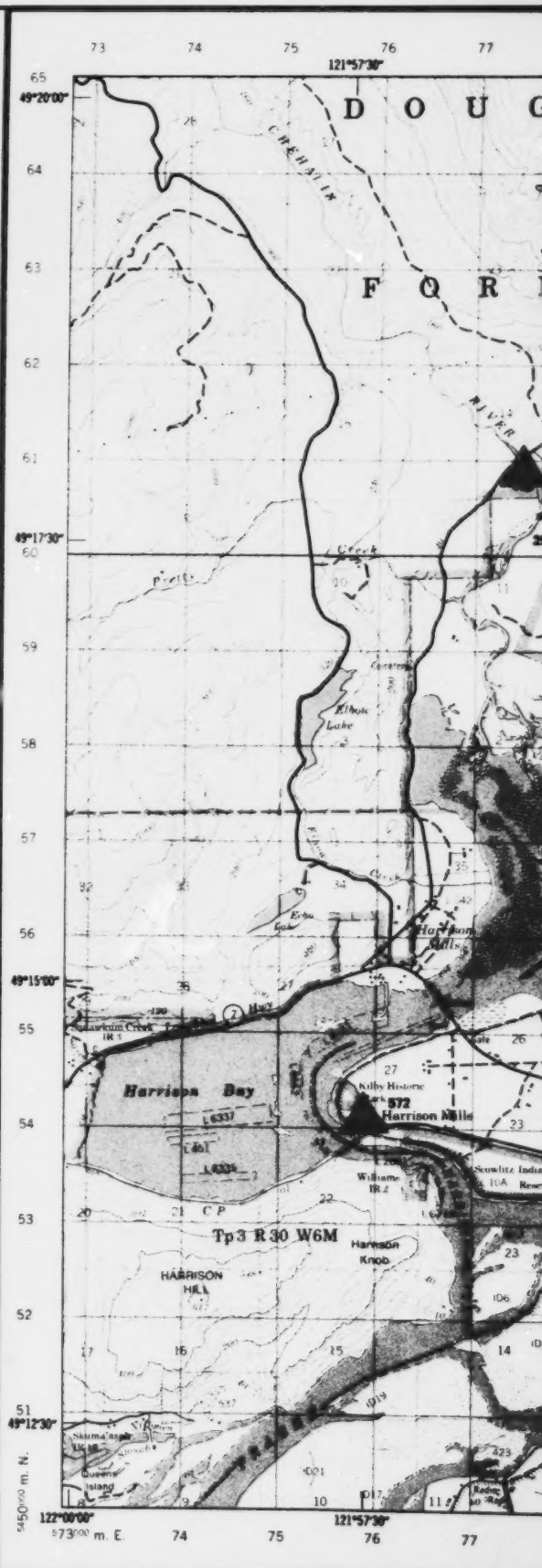

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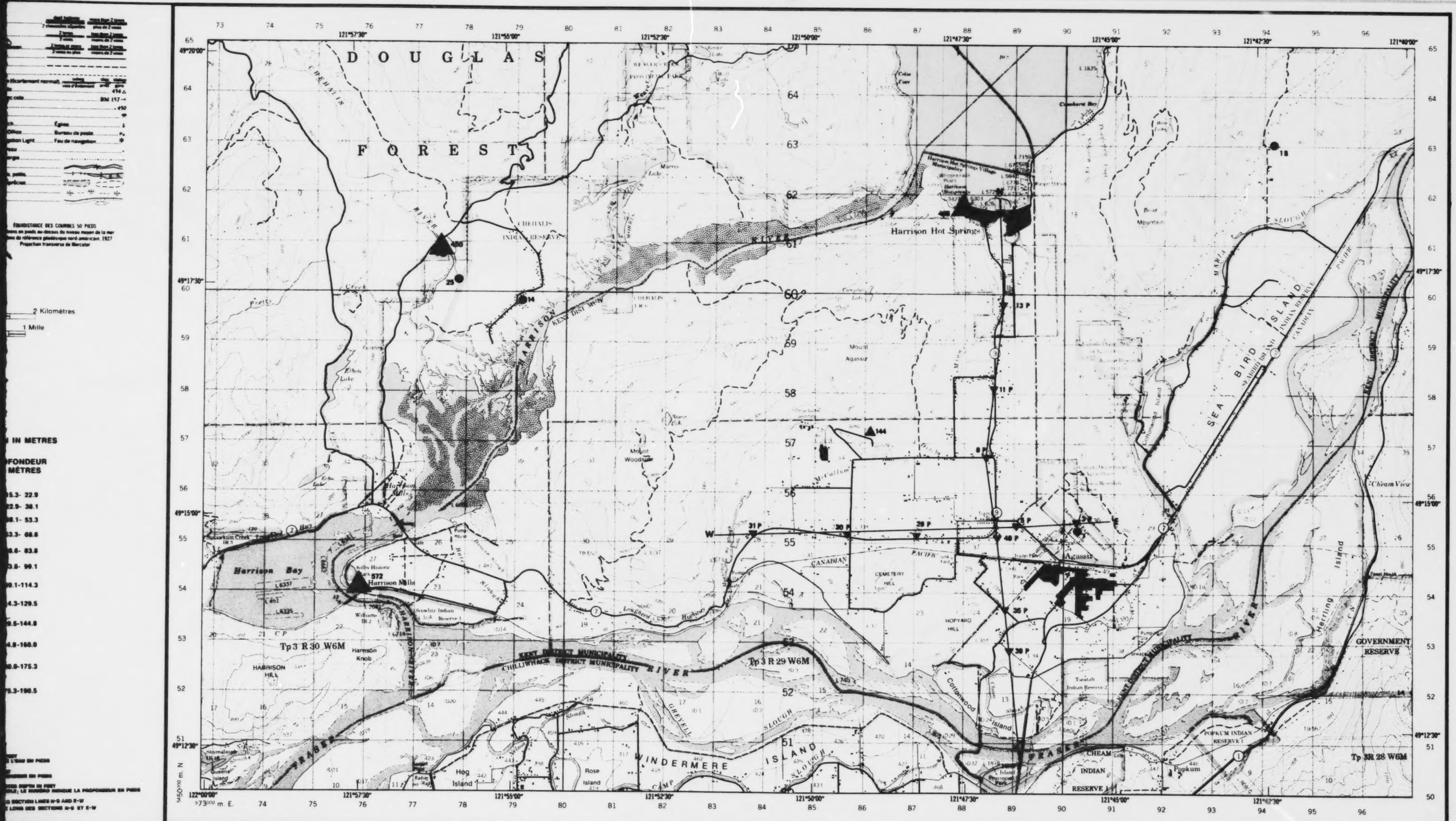
FIGURE 31. WELL AND PIEZOMETE

FIGURE 31. EMPLACEMENT DES PUITS ET DES PI


DOUGLAS
FOREST
Harrison Hot Springs
Harrison Bay
Harrison Mills
Tp 3 R 30 W6M
Tp 3 R 29 W6M
Tp 3R 28 W6M
KENT DISTRICT MUNICIPALITY
CHILLIWACK DISTRICT MUNICIPALITY
FRASER RIVER
HARRISON RIVER
WINDERMERE ISLAND
SEA BIRD ISLAND
Hog Island
Rose Island
Cottonwood Island
Herring Island
Agassiz
CHEAM INDIAN RESERVE 1
GOVERNMENT RESERVE
Cheam View
Mount Woodside
Mount Agassiz
Bear Mountain
CHEHALIS INDIAN RESERVE
Sowaluk Indian Reserve
Tzeachten Indian Reserve
Popkum Indian Reserve 1
CANADIAN PACIFIC
CEMETERY HILL
HOPYARD HILL
HARRISON HILL
Harrison Knob
Kilby Historic Park
Aquarium Creek IR 5
Williams IR 2
Elbow Lake
Morris Lake
Mount Woodside
Provincial Park
Trailer Park
Pump House
Ferry
Radio Beacon
Camp
Slough
Creek
Island
Point
Bay
Mountain
Lake
Marsh
Flats
Cliff
Ridge
Valley
Highway
Trans-Canada Highway
Yale Road
Lougheed Hwy
Kent Dist. Main
Chilliwack Dist. Main
Harrison Mills Village
Harrison Hot Springs Village
Harrison Hot Springs Public Beach
Harrison Hot Springs Public Wharf
Harrison Hot Springs Public Golf Course
Harrison Hot Springs Trailer Park

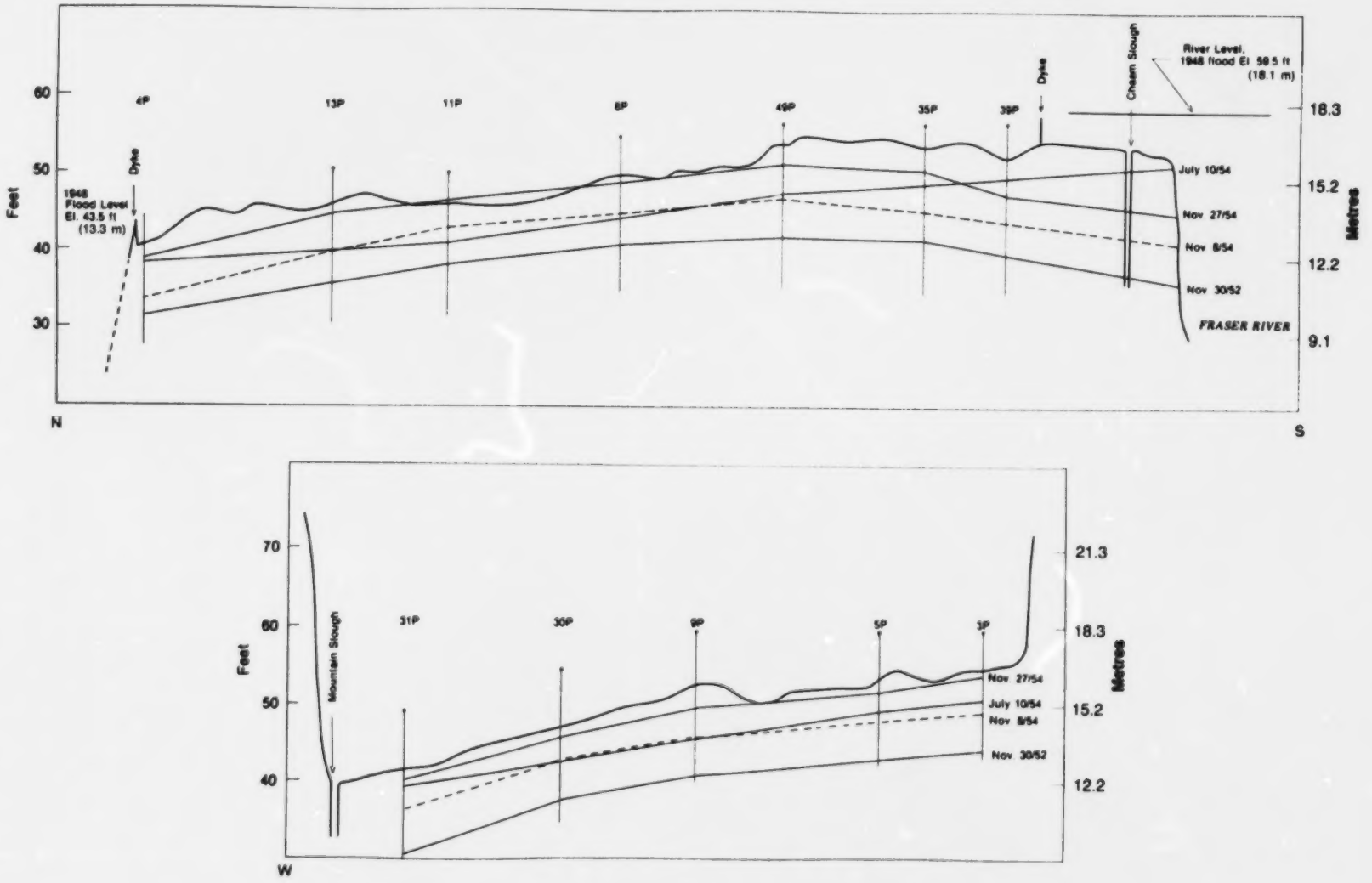


Figure 32. Water table profiles, Agassiz area during flood stages on Fraser River.

HYDROCHEMISTRY

Ground water in the Fraser Lowland originates from rainfall and snowmelt which infiltrate into the soils and rocks and eventually return to the surface at natural or man-made discharge points. All ground water contains constituents derived from the natural environment or from the waste products of man's activities. From the point of recharge to the point of discharge the chemical quality of ground water changes by increasing in total dissolved and suspended solids and by the relative proportions of constituents.

The quality of the ground water evolves from precipitation which is charged with CO_2 and enters the water table as a weak acid HCO_3 to saline water, with total dissolved solids in the order of 6000 mg/L. The quality at any point in time depends on a complex system of flow controlled by the topographic relief and the underlying geologic materials.

From its recharge in the uplands, such as Sunnyside, Clayton or Langley, ground water follows paths which are local, intermediate and regional in extent. Ground water in local flow systems has a relatively short residence time, probably not more than 25 years, and its total dissolved solids do not exceed 120 mg/L. Local flow systems are present in hydrostratigraphic unit C and are also recognized in the uplands in hydrostratigraphic unit A, where springs commonly discharge at elevations in the order of 60 m above mean sea level to form the headwaters of numerous streams. Intermediate flow systems are resident in confined aquifers and multi-till sequences, such as hydrostratigraphic unit D. The age of the water is probably in the range of 10 to 100 years, and chemical evolution has progressed with an increase in total dissolved solids ranging up to 500 mg/L. Regional flow systems are present in hydrostratigraphic unit E, where ground-water residence times probably span hundreds of years, and chemical evolution has produced saline water with total dissolved solids as much as 6000 mg/L.

Ample supplies of good quality ground water are commonly found within local and intermediate flow systems in the Fraser Lowland and water quality problems are limited to the presence of iron and manganese. Figure 33 illustrates the average chemical quality of ground water found in the major aquifers within the Fraser Lowland.

Evaluation of Water Quality Analyses

More than 800 samples of ground water collected from wells and springs in the Fraser Lowland have been analyzed in the laboratories of the Water Quality Branch, Environment Canada, and its predecessor, the former Health and Welfare Branch. The analytical methods used are described in the methods manual published by Environment Canada (1974). The analytical results are stored in the computerized National Water Quality Data Bank, NAQUADAT, operated by the Water Quality Branch, Inland Waters Directorate, Environment Canada, Ottawa.

In the following paragraphs the major chemical constituents and chemical properties of ground water are discussed. Appendix A, Table A-1, indicates the acceptable raw water quality levels for drinking water supplies. Any water sample that exceeds the acceptable level in one or more constituents or property should be assessed individually with respect to its suitability and safety from health, aesthetic and other viewpoints.

Selected Physical and Chemical Parameters

Alkalinity

Alkalinity, which is expressed as an equivalent of calcium carbonate ($CaCO_3$), is the measure of a water's capacity to neutralize an acid. Bicarbonates (HCO_3^-), carbonates (CO_3^{-2}) and hydroxides (OH^-) are commonly reported as causing alkalinity. Ground water in the Fraser Lowland may have carbonates greater than 10 mg/L and bicarbonates in excess of 500 mg/L, which contribute to alkalinity values greater than the acceptable limit of 500 mg/L. High alkalinities are found in ground water in hydrostratigraphic unit D, and where they exceed the acceptable limit they may cause the water to have an unpleasant taste. Also, the establishment of poultry farms where ground water has high alkalinities is discouraged, because the poultry there suffer from diarrhea.

Calcium and Magnesium

Calcium and magnesium are the most common constituents found in natural waters. They are readily dissolved from many rocks and leached from the soils. The ground waters of the Fraser Lowland typically have concentrations of less than 15 mg/L of calcium, well below the acceptable limit of 200 mg/L. Even in those deeper regional flow systems found in Nicomekl-Serpentine valleys, the calcium values rarely exceed 30 mg/L. A test hole drilled to a depth of 180 m in section 20, township 11, found a confined regional flow system that produced ground water with a total dissolved solids value of 5400 mg/L, of which 165 mg/L was calcium. The only other anomalous calcium type ground water was found in a confined aquifer at a depth of 62 m in section 25, township 7, which produced ground water with total dissolved solids of 1300 mg/L, of which 361 mg/L was calcium.

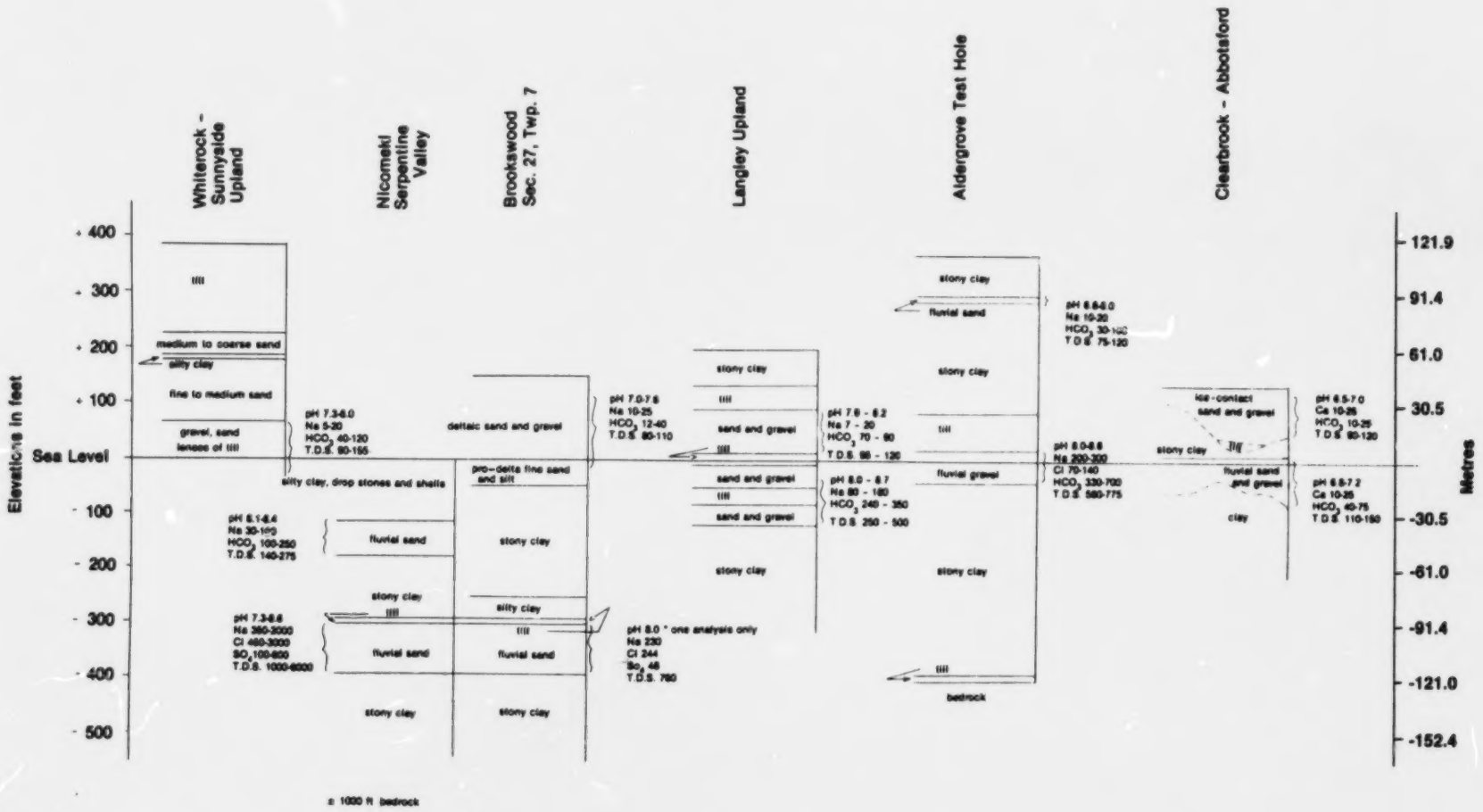

Whiterock - Sunnyside Upland
Nicomekl Serpentine Valley
Brookswood Sec. 27, Twp. 7
Langley Upland
Aldergrove Test Hole
Clearbrook - Abbotsford
Elevations in feet
Sea Level
Metres
+ 400
+ 300
+ 200
+ 100
- 100
- 200
- 300
- 400
- 500
121.9
91.4
61.0
30.5
-30.5
-61.0
-91.4
-121.0
-152.4
medium to coarse sand
silty clay
fine to medium sand
gravel, sand lenses of till
pH 7.3-8.0 Na 5-20 HCO3 40-120 T.D.S. 80-155
silty clay, drop stones and shells
pH 6.1-6.4 Na 30-140 HCO3 100-250 T.D.S. 140-275
pH 7.3-8.6 Na 350-3000 Cl 460-3000 SO4 100-600 T.D.S. 1000-6000
fluvial sand
stony clay
deltaic sand and gravel
pro-delta fine sand and silt
pH 7.0-7.6 Na 10-25 HCO3 12-40 T.D.S. 80-110
pH 8.0 * one analysis only Na 230 Cl 244 SO4 46 T.D.S. 700
sand and gravel
pH 7.6 - 8.2 Na 7 - 20 HCO3 70 - 80 T.D.S. 98 - 120
pH 8.0 - 8.7 Na 80 - 180 HCO3 240 - 350 T.D.S. 250 - 500
bedrock
pH 8.0-8.6 Na 200-300 Cl 70-140 HCO3 330-700 T.D.S. 580-775
ice - contact sand and gravel
pH 6.5-7.0 Ca 10-25 HCO3 10-25 T.D.S. 80-120
pH 6.5-7.2 Ca 10-25 HCO3 40-75 T.D.S. 110-160
clay
± 1000 ft bedrock

Figure 33. Water quality, Fraser Lowland aquifers.

Magnesium concentrations are commonly less than 10 mg/L, with values up to 30 mg/L in deeper confined flow systems. None of the ground water sampled has concentrations high enough, when coupled with high sulphates, to produce laxative effects.

Chloride

Chlorides may be the result of mineral dissolution but are most likely derived from connate waters in the unconsolidated silty clays deposited under marine conditions. Chlorides are found in the Fraser Lowland in concentrations up to 2500 mg/L in slow-moving or regional flow systems by wells penetrating the deeper confined aquifers, especially in the Nicomekl-Serpentine Valley. In the upland area, isolated deep wells have also found saline ground water. For example, a well drilled to a depth of 70 m in section 10 found water with 1150 mg/L chloride. Figure 34 (in pocket) indicates chloride distribution as determined from analyses, and as expected, high chloride concentrations are associated with regional flow systems. Chlorides may restrict the use of the water for people with heart and kidney ailments. Chlorides have a significant effect on corrosion of steel and aluminum; hence well casings may have to be replaced more frequently during the life of the well.

Where the concentrations of chloride are extremely high, attempts to improve the water quality by continuous pumping over a period of several days commonly fail. A test hole in section 19, township 11, drilled to a depth of 150 m in October 1975, found confined ground water with chlorides in the order of 3820 mg/L. The well was left free-flowing with discharge into a nearby creek; after a period of 40 months and an estimated discharge of 4.1×10^5 m^3 the chloride concentration has been reduced to 860 mg/L, which is a more typical chloride level for ground water in the area.

Colour

Colour is measured as true colour and as apparent colour. True colour is a measure of the dissolved colouring compounds, whereas apparent colour measures both dissolved and suspended material in the sample. Commonly colour values are less than 10, but where iron and manganese concentrations are high colouring is noticeable. Colouring may also be due to decaying vegetation, such as humic substances, tannins and lignins. Buried peat layers may be found at depth, and where wells are completed in these aquifer materials, brownish colouring results. Attempts to remove colouration are futile, and examples are known where ground water treated to remove colours that were thought to be due to iron were found, upon examination of the driller's logs, to be due to tannins from buried peats. Colour is aesthetically undesirable; it can infiltrate foods and will discolour dressed poultry.

Fluoride

Water quality analyses indicate that all ground water derived from aquifers within the surficial deposits in the Fraser Lowland has concentrations of fluorides less than 10.0 mg/L, and in most instances the concentration is less than 0.1 mg/L.

Fluorides in concentrations less than 1.2 mg/L have been proven to be beneficial in reducing tooth decay in all regions of Canada (McNeely *et al.*, 1979). The only instances of fluoride concentrations exceeding this level are found in ground waters recovered from drilled wells penetrating sandstones and shales that flank the southeast side of Grant Hill in townships 12 and 15. Skeletal effects from cumulative fluorosis are suspected for users of these ground waters, which have fluoride concentrations of 5.8 mg/L. For this reason, one well on Whonock Indian Reserve No. 1, reporting more than 8.0 mg/L, was abandoned.

Hardness

Hardness is influenced by calcium, magnesium, carbonate and bicarbonate concentrations and is noted for its capacity to limit soap sudsing. Water is classified as soft when hardness measured as $CaCO_3$ is less than 60 mg/L, moderately hard between 60 and 120 mg/L, and hard where values exceed 120 mg/L. Almost all ground waters in the Fraser Lowland are classified as soft to moderately hard and are of the sodium bicarbonate type.

Iron and Manganese

Iron is present in all ground waters. It is more of a problem in those supplies obtained from water table aquifers where rain water, a weak carbonic acid, dissolves iron to form ferrous bicarbonate. This mobile ion, once below the water table, remains in the ferrous state, but when pumped to the surface and exposed to air oxidizes to the less mobile ion, ferric hydroxide and precipitates, producing a reddish-brown stain on porcelain, plumbing, clothing and especially dairy equipment. The water is clear when pumped, but upon standing turns yellow and a reddish flocculent settles out.

An acceptable limit is placed at 0.3 mg/L for aesthetic reasons, and beyond 1.0 mg/L the water has an objectionable bitter-sweet astringent taste. Removal of iron is one of the more difficult processes and is effective at low concentrations only. The usual procedure is to filter the pre-

cipitated ferric hydroxide through an activated charcoal filter, but the effectiveness of the method is dependent on the pH as well as the alkalinity of the water. Processes of ion-exchange used in water softeners may also be effective, but in most cases a combination of both ion-exchange and filtration is required, and the treatment becomes not only elaborate but expensive and difficult to maintain. Consequently, unless the iron content is maintained at 0.3 mg/L or less, the treatment must be considered inadequate.

Manganese is similar to iron in its chemical behaviour and is commonly found in association with iron. It is an essential nutritional requirement to both humans and animals. One of its sources is the decomposition of organic material. Hence, ground water in water table aquifers in areas where agriculture practices such as dairying are carried out may accumulate higher concentrations of manganese. Concentrations of manganese in ground water in the Fraser Lowland are generally less than 0.01 mg/L but range up to 0.04 mg/L. Like iron, manganese causes staining, and when combined with chloride-based cleansers poses a problem, especially for cleaning and sterilizing dairy equipment, because it produces an ink-black manganese chloride solution. Removal of manganese, as of iron, is a process of filtration and ion-exchange, but where levels exceed 2.0 mg/L, oxidizing filters or oxidation filtration methods must be used.

Nitrates

Nitrates in ground water can be attributed to a number of sources, namely, the atmosphere, legume plants, decaying plant debris, manure, sewerage, nitrogenous fertilizers and industrial wastes. Concentrations in ground water are generally low, but where values are greater than 10 mg/L NO_3 as N, contamination from manure, sewerage or septic tank discharge is suspect. It is not uncommon in the Fraser Lowland for shallow dug wells within water table aquifers to become contaminated by leachate from manure stockpiles, mainly poultry manure. Because winter months have heavy rainfalls, the highly soluble nitrates are readily transported to the water table.

Fourteen wells and three creeks were monitored for nitrates at approximately six-week intervals from January 1978 to December 1981. It was found that fluctuations of nitrate levels did not occur in all wells, nor did they occur seasonally. Figure 35 illustrates the nitrate concentrations in six representative wells and one creek. Three of the wells show a continued increase in nitrate levels up to the end of 1981. The well at Agriculture Canada's building (500 block - 320 St.) receives nitrate from fertilizers used on their test plots; the school well (23752 - 52 Ave.) is probably partially recharged with effluent from the septic tank drainage field or fertilizers applied to the playing fields; and the dug well (24846 - 57 Ave.) is vulnerable to surface contaminants such as garden and lawn fertilizers. The peak in nitrate in May for the shrubbery well (23441 - 48 Ave.) was directly due to the stockpiling of poultry manure. All the other wells and creeks indicated only minor changes in nitrate levels. All the wells penetrated water table aquifers at depths from 5 to 50 m below the surface.

For health reasons, the acceptable limit of NO_3 is 10 mg/L. The consumption of waters with high nitrate concentrations decreases the oxygen-carrying capacity of the blood. Therefore it is particularly important that such contaminated waters are not used to prepare food for infants. Water contaminated by NO_3 can deplete the oxygen from the limited blood supply of an infant, resulting in methemoglobinemia, which can lead to death by asphyxia. Only one such case has been reported to date in the Fraser Lowland and that resulted from an infant being fed formulae with ground water containing 80 mg/L nitrates as nitrogen. It is also believed, but not proven, that abnormal mortality rates for newborn mink have a similar cause.

Apart from the health hazard, nitrates are undesirable because they stimulate plant growth, and, where carried into streams, rivers or lakes by ground water discharge, cause eutrophication. Such water courses will become clogged with excessive weed and algae growth. In most cases where nitrate contamination exists in the Fraser Lowland it can be linked to a point source.

Phosphate

Within the Fraser Lowland, ground water recovered from the deeper confined aquifers below the till has been found in some instances to contain phosphate exceeding the acceptable level of 0.2 mg/L. Ground water found in such aquifers, in a number of test holes drilled in Langley District Municipality, had to be rejected for municipal use because phosphate levels exceeding 0.2 mg/L promote the growth of algae in reservoirs and water storage towers. Although phosphates are derived from the decomposition of organic materials, sewerage and fertilizers, their presence in the water table aquifers of hydrostratigraphic units A and C has not been detected to date in excess of acceptable limits.

Hydrogen Ion (pH)

The pH or hydrogen ion concentration indicates how acidic (values less than 7) or how basic (values greater than 7) water is. All reported pH values were measured in the laboratory and do not accurately reflect field conditions. Throughout much of the Fraser Lowland, especially

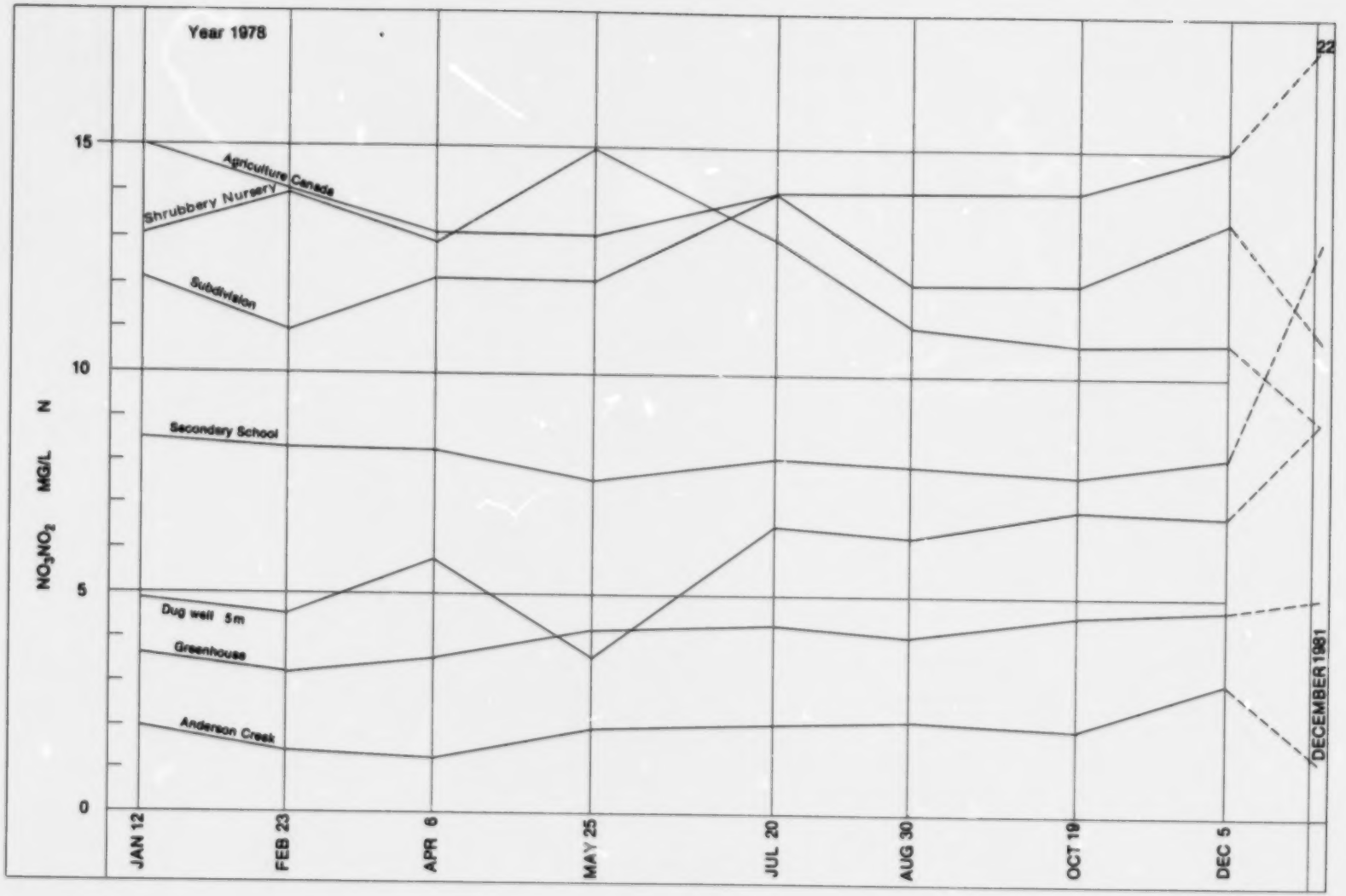


Figure 35. Nitrate levels.

in water table aquifers, pH values are less than 7. These acidic waters corrode copper pipes, which rarely last beyond 15 years. On the other hand, low pH values are beneficial, for example, in some greenhouse operations, especially for the culture of azaleas.

Sodium and Potassium

Sodium is a major constituent of all ground water in the Fraser Lowland. Concentrations in water table aquifers range from 2 to 25 mg/L, but in the deeper confined aquifers concentrations may range as high as 900 mg/L. Perhaps the most significant effect of high sodium concentration is related to irrigation. Excessive sodium in irrigation water will result in base exchange reactions with soils, whereby the calcium and magnesium in the soil are replaced by sodium. This leads to the creation of an alkali soil which has limited agricultural value. In most areas of the Fraser Lowland where irrigation is required, the available ground water has very low concentrations of sodium, but this is not the case in the Nicomekl-Serpentine Valley where the ground water has not only high concentrations of sodium but of chloride as well.

Potassium concentrations are low, commonly less than 6 mg/L, and are insignificant.

Specific Conductance and Total Dissolved Solids

Specific conductance is a numerical expression of a water's ability to conduct an electrical current measured in microsiemens per centimetre (μS/cm) corrected to a standard temperature, usually 25°C. The specific conductance is proportional to total dissolved solids and inversely proportional to temperature. In general, specific conductance multiplied by a factor of 0.65 (McNeely *et al.*, 1979) will give an estimate of the total dissolved solids in ground water.

Sulphate

Sulphate is present in low concentrations in most ground water in the Fraser Lowland. It is present in concentrations greater than 200 mg/L in only a few instances in highly mineralized waters of the regional flow systems. For drinking purposes, a preferred limit of 250 mg/L is proposed, but concentrations up to 500 mg/L are acceptable. High concentrations limit the usefulness of the water for ice making because, combined with sodium, the sulphate causes a white shell in the ice (McNeely *et al.*, 1979). Also, sulphate combined with magnesium may be cathartic to humans.

Taste and Odour

Unpleasant odours and tastes are associated with a great variety of substances. The most common odour is hydrogen sulphide gas (H_2S) with the characteristic odour of rotten eggs. Many well owners experience this problem, and its origin is the bacterial degradation of naturally deposited organic matter within the producing aquifer. Although H_2S is a highly soluble and poisonous gas, concentrations in ground water are low enough that it is unlikely that anyone could ingest harmful doses. Iron bacteria found in a number of drilled wells impart an earthy smell to the water and produce a reddish slime or sludge. Contamination from sewerage or septic tanks as well as landfill effluent may also impart a foul odour to groundwater supplies.

The problems of odours in wells can be alleviated by a regular program of disinfection to kill the potentially dangerous organisms that may be present. Chlorination is by far the most common means of disinfecting wells and water supplies.

Ground-Water Temperature

Ground-water temperatures measured at the well head of a number of flowing artesian wells in the Fraser Lowland range between 9°C and 10°C. Similar temperatures have been recorded during pump tests of wells producing from unconfined as well as confined aquifers. However, a temperature of 11.6°C recorded at a flowing artesian well, 118 m deep, at Chilliwack River Salmon Hatchery, Slesse Creek, remained constant during a pump test of 9450 min at a rate of 130 L/s (Table C-1, Well No. 52).

A temperature probe lowered into the test hole drilled at Aldergrove with a static level of 56 m recorded the following temperatures: at 60 m, 9.7°C; at 75 m, 10°C; at 120 m, 10.6°C; at 180 m, 10.8°C.

Pollution

Ground water becomes contaminated with any alteration of its quality in an undesirable manner, whereas pollution is the contamination of a water to the point where it is unfit for a particular use. Much of the Fraser Lowland, with its surficial sands, silts and gravel deposits, is vulnerable to contamination. As the area is agriculturally oriented, common sources of potential contaminants include generous applications of fertilizers, pesticides and irrigation water plus improper management of animal wastes, notably from poultry, cattle and mink.

Pollution has occurred in several localities, especially in section 21, township 7, where a point source is evident. Leachate from piles of animal waste has infiltrated to water table aquifers (Fig. 36) and its presence causes a rapid increase in nitrate-nitrogen as well as, in some cases, an odour or discolouration. To prevent future contamination, these wastes can be stored on concrete pads with a curb rim, so that leachate can be collected and removed to a treatment plant. Contamination from excessive applications of chemical fertilizers and pesticides has not been evident to date.

Many of the country's residential homes are not connected to sewers, and wastewater is discharged to septic tank systems which percolate liquid effluent into the soil. Generally, the soils purify the effluent by bacterial action, filtration and chemical processes, but the systems can fail despite municipal building codes regulating the installation of these septic systems. The water table may rise rapidly in some places, owing to above normal precipitation during the winter months, and the septic systems discharge wastes into the saturated aquifer. Bacteriological analyses are then carried out on suspect wells and a coliform count is determined. Coliform bacteria are usually harmless and water containing coliform bacteria still may not contain any pathogenic organisms. A water analysis with positive identification of coliform bacteria, however, implies a potential danger. A common remedy is to sterilize the well by adding a chloride agent.

Abandoned gravel pits were formerly common sites for landfills in the Fraser Lowland. In most instances the gravel operation ceased when the water table was exposed. The dumping of garbage in these areas permits direct introduction of leachate into the aquifer. The potential for contamination is great and corrective measures may not be successful.

Minor contaminant sources include spills from fuel tanks and possible derailments of dangerous cargo, but in such cases the source is evident and can usually be removed without too much difficulty.

GROUND-WATER USE AND MANAGEMENT

The 1915 inventory found 165 wells in the Nicomekl-Serpentine and Hazelmere valleys discharging by free flow an estimated 2.25×10^6 m^3 of water per year. With the exception of two, these wells are no longer in existence, but the 1976 inventory of flowing artesian wells in British Columbia (Johanson, 1976) indicates approximately 460 wells in the same areas, all of larger diameter (150 mm, as compared with 50 mm in the old wells) also discharging under flowing artesian conditions. The flow rates in most of these wells have been reduced, either by extension of a standpipe or installation of a valve, so that flows are in the range of 0.3 L/s. Even with controlled flow, annual discharge of this ground water would total more than

Figure 36. Mushroom manure stockpiled in abandoned gravel pit in which water table is at or near the surface of the pit.

4.8×10^6 m^3. Therefore the waste of ground water in the above area has more than doubled. A flowing artesian well field in the vicinity of 56 Ave. and 232 St. has caused an additional drain in the order of 3.68×10^5 m^3 annually, bringing the total discharge due to flowing artesian wells in the Fraser Lowland to more than 5.1×10^6 m^3.

Surrey and Green Timbers Nurseries require an estimated 2.7×10^4 m^3 annually for irrigation, but withdrawal for irrigation elsewhere has not been estimated. The principal crops requiring irrigation, namely, strawberries, raspberries and cole crops, are cultivated on soils classified as Abbotsford soils and complexes dominated by Abbotsford soils (British Columbia, 1981) that are rapidly drained and require irrigation in most years during June and July. These soils, covering 5070 hectares in the Fraser Lowland, have developed from underlying materials, mostly gravel and sand, that provide water table aquifers in which irrigation wells can be installed and developed to supply the required water, commonly in volumes greater than 4 L/s. Formerly all irrigation was carried out by overhead sprinklers, but more recently the installation of drip irrigation systems, especially for raspberries, has provided greater conservation of the ground-water resources.

Ground-water resources are essential for fish culture in the British Columbia Coastal area. Research has established that andronomous fish return to spawning grounds in creeks where ground water with inherent constant temperature discharges. The ground water with temperatures close to 10°C provides a controlled temperature medium for incubation. Therefore, to enhance the production of andronomous fish, a number of fish hatchery facilities have been built adjacent to creeks and streams where ample volumes of ground water can be extracted from permeable sediments (Table C-1, Wells Nos. 48 and 52). The Abbotsford Trout Hatchery (Table C-1, Well No. 46) requires more than 4.2×10^6 m^3 of water annually for its operation, and much of the water is purified and recycled. Also, within the Fraser Lowland eight trout-rearing farms are in operation, and these farms require 10 to 15 L/s of flowing artesian ground water.

Most industries requiring large volumes of water are located close to water sources supplied by the regional water distribution system of the Greater Vancouver Water District. Industrial users include mainly food processing plants, for example, the Empress Foods Processing Plant, Clearbrook, where ground-water consumption during 1981 totalled more than 1.84×10^5 m^3. The washing of aggregates is also a major consumer of ground water (Table C-1, Wells Nos. 34 and 39, and Fig. 37), but the gravel operations recycle the process water within the pit.

Figure 37. Aggregate quarry, well site No. 34, Table C-1.

During 1981, about 2.1×10^7 m^3 was pumped from production wells in the Fraser Lowland to supply municipal, irrigation and industrial needs (Table 3). In addition, a significant percentage of the total population was relying on private wells. A conservative estimate suggests that a volume of 8.5×10^6 m^3 of ground water is extracted annually from private wells. In contrast, surface water requirements totalled 3.6×10^7 m^3. Therefore, ground water accounts for more than 44% of the total water consumption in the Fraser Lowland.

The management of ground-water resources lies directly with the well owner, whether it is a municipal well, a production well belonging to a subdivision, a water supply company or a private house or farm well. To protect this renewable resource, some management policies should be applied. First, in those areas of flowing artesian wells it is advisable to control the flow, either by installing a valve or extending the standpipe, so that only a limited amount of water is wasted and the hydrostatic head of the ground water within the aquifer is not substantially reduced, causing a reduction in flow and piracy of water from neighbouring wells. Secondly, any irrigation or production well should be test pumped, not only to arrive at a production pumping rate but also to determine the potential for well interference and overpumping of the aquifer system. Thirdly, to protect water quality, the hydrogeology of all sites for such facilities as sanitary landfills should be intensively investigated and dumping in abandoned pits prohibited. Fourthly, agricultural practices should be regulated regarding the application of fertilizers and chemicals as well as the disposal of animal wastes. Fifthly, the installation of septic fields should be discouraged in some areas, and land development should be contingent on other means of sewage disposal.

CONCLUSION

The surficial deposits, that is the clays, silts, sands, gravels and tills in the Fraser Valley, can be divided into five hydrostratigraphic units; the 6th unit is bedrock. A permeable sand and gravel unit with local ground-water flow systems (unit C) provides the most productive aquifers. The multi-till layer (unit D) hosts confined aquifers with intermediate flow systems. Regional flow systems are confined to the older silty sand sequences of unit E found at greater depths within the lowland.

Most of the surficial deposits at or near the surface are permeable. Therefore, much of the lowland is a zone that effectively collects and stores precipitation during the period November to April. The records of observation wells indicate that the water table fluctuations may vary as much as 8 m during seasons of above normal precipitation.

It is not uncommon, especially in water table aquifers, to install production wells for municipal, agricultural and industrial use, as well as for water distribution to areas where the potential for ground-water development is limited.

Failure of ground-water supplies due to a shortage of water is generally seasonal and occurs in those areas where water tables have been lowered by overpumping to supply water mainly for irrigation. The immediate solution is to deepen the well, but often winter recharge restores the supply.

Water within the water table aquifers commonly has total dissolved solids less than 100 mg/L. The ground water in these aquifers generally has a low pH, resulting in corrosive properties. Within the intermediate flow systems, the confined ground water has a total dissolved solids concentration ranging from 150 to 500 mg/L, composed mainly of sodium and carbonate. Total dissolved solids are greater than 1000 mg/L in the deeper regional flow systems, where residence times may be several hundred years and ground-water movement is slow.

Iron and manganese are the most troublesome water quality parameters in the Fraser Lowland and are prevalent in many of the water table aquifers. The removal of these constituents can be difficult, but filtration and water softening methods are effective in some cases. Slimes associated with iron bacteria can be corrected by chlorination and surging of the well screen.

Aquifer contamination has occurred in the Fraser Lowland, but in most cases a point source, such as a manure stockpile, a nearby landfill or seepage from buried fuel tanks, can be identified.

Total water consumption for the year 1981 in the area included in this report is estimated to be 6.7×10^7 m^3 and of this total, 3×10^7 m^3, or 44%, represents the ground-water contribution.

Table 3. Water Consumption in the Fraser Lowland (m^3/yr)

District or water works	Population (1981 Census)	Production wells	Ground water pumped from production wells (1981)	Ground water estimated from other sources	Surface water consumption (1981)
Abbotsford District Municipality	12 745	Abbotsford No. 2	107 976		
		Freeway-McCallum Rd.	33 948		
		Riverside No. 1	710 905		
		Riverside No. 2	441 425		
		Farmer Rd. No. 1	468 238		
		Clayburn	598 685.5		
Agassiz-Kent district	3 394			Domestic wells 280 000	
Chilliwack District Municipality	40 462	Watson Rd.	2 389 500		Elk Creek 1 272 880
		CFB Chilliwack	621 778		
Langley District Municipality	44 617	CFB Aldergrove	250 489	Larco Subdivision 22 730	City of Langley 2 643 722 (Greater Vancouver water district)
		Tall Timbers	16 365	Domestic wells 1 250 000	
		Murrayville No. 1 and 2	218 208		
		Brookwood:			
		No. 7	273 096		
		No. 6	169 711		
		No. 5	141 494		
		No. 4, 2 and 1	358 305		
		Willoughby	185 510		
		Ben Pel	23 512		
		Trustcan	7 319		
		F. Knolls	25 544		
		Fort Langley			
		No. 1	408 049		
		No. 2	243 847		
		Aldergrove			
		No. 3	191 210		
		No. 4	74 924		
		No. 7	389 899		
Maple Ridge District Municipality	32 232			Domestic wells 2 220	Greater Vancouver water district 4965 X 1000
Matsqui District Municipality	42 000	Clearbrook Water Works	931 857	Domestic wells 1 000 000	
		Marshall Rd.	2 928 976		
		Hazelwood	103 073		
		Townline	1 639 365		
		Mt. Lehman	288 480		
		Lefeuvre	60 559		
		Bradner	79 177		
Mission District Municipality	20 056			Domestic wells 1 103 760	Cannell Lake 2 153 865
Surrey District Municipality	147 138	Blaine	82 964	Flowing wells 4 835 520	Greater Vancouver Water district 25 925 X 1000
Whiterock Water Works	13 391		2 918 310	Extra summer peak 25 000	
Industrial		Empress Foods, Clearbrook	184 026	Irrigation, forest nurseries, Surrey 27 000	
		Trout Hatchery, Abbotsford	4 228 052		
Totals			21 010 569	8 546 230	36 960 467

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Appendix A
Acceptable Water Quality Levels

APPENDIX A

ACCEPTABLE WATER QUALITY LEVELS

The uses for which ground water is suited are determined by the constituents found in the water, as well as its properties. Water samples are commonly analyzed for the following ionic constituents: calcium, magnesium, sodium, potassium, bicarbonate, carbonate, sulphate, chloride, fluoride, nitrate, iron and manganese, and the nonionic constituent silica. Many of the constituents, both ionic and nonionic, impart certain quality characteristics that may be termed properties. The most significant properties include pH, hardness, alkalinity, taste, odour, turbidity, total dissolved solids and specific conductance. Nitrogen in the form of nitrite-nitrogen, nitrate-nitrogen, free ammonia nitrogen and albuminoid nitrogen, is analyzed to give indications of contamination.

Table A-1 indicates the maximum acceptable levels of the various constituents and properties in water used for domestic consumption.

Table A-1. Maximum Acceptable Levels in Water Used for Domestic Consumption

PARAMETER	LEVEL			REFERENCE
ALKALINITY, TOTAL, as $CaCO_3$	GE	30	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
	LE	500	mg/L	
AMMONIA, as N	LE	0.5	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
ARSENIC, as As	LE	0.05	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1979
BACTERIA, FECAL COLIFORM		ND	No./dL	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1979
BACTERIA, TOTAL COLIFORM	LE	10	No./dL	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1979
BARIUM, as Ba	LE	1.0	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1979
BORON, as B	LE	5.0	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1979
CADMIUM, as Cd	LE	0.005	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1979
CALCIUM, as Ca	LE	200	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
CESIUM-137	LE	50	Bq/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
CHLORIDE, as Cl	LE	250	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1979
CHROMIUM, as Cr	LE	0.05	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1979
COLOUR	LE	15	TCU	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1979
COPPER, as Cu	LE	1.0	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1979
CYANIDE, as CN	LE	0.2	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1979
FLUORIDE, as F	LE	1.5	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1979
HARDNESS, TOTAL, as $CaCO_3$	LE	120	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
IODINE-131	LE	10	Bq/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
IRON, as Fe	LE	0.3	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1979
LEAD, as Pb	LE	0.05	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1979
MAGNESIUM, as Mg	LE	150	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
MANGANESE, as Mn	LE	0.05	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1979
MERCURY, as Hg	LE	1.0	µg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1979
NITRATE + NITRITE, as N	LE	10.0	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1979
NITRITE, as N	LE	1.0	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1979
NTA, as H_3NTA	LE	50.0	µg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1979
OIL AND GREASE		ND	mg/L	ENVIRONMENTAL STUDIES BOARD, 1973, EPA.R3.73.033
pH	GE	6.5		DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1979
	LE	8.5		
PHENOLIC SUBSTANCES, as PHENOL	LE	0.002	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1979
PHOSPHATE, TOT.INORG., as P	LE	0.085	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
PHOSPHATE, TOTAL, as P	LT	0.100	mg/L	U.S. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
PHOSPHORUS, as P	LE	0.2	mg/L	HART, 1974, AUSTR. WAT. RES. COUNCIL, TECH.PAPER 7
α– RADIATION, TOTAL	LE	0.02	Bq/L	ENVIRONMENTAL STUDIES BOARD, 1973, EPA.R3.73.033
β– RADIATION, TOTAL	LE	0.19	Bq/L	ENVIRONMENTAL STUDIES BOARD, 1973, EPA.R3.73.033
RADIUM-226	LE	1.0	Bq/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1979
SELENIUM, as Se	LE	0.01	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1979
SILVER, as Ag	LE	0.05	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1979
SODIUM, as Na	LE	270	mg/L	HART, 1974, AUSTR. WAT. RES. COUNCIL, TECH.PAPER 7
STRONTIUM-90	LE	10	Bq/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1979
SULPHATE, as SO_4	LE	500	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1979
SULPHIDE, as H_2S	LE	0.05	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1979
SURFACTANTS, as MBAS	LE	0.5	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
TEMPERATURE	LE	15	°C	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1979
TOTAL DISSOLVED SOLIDS	LE	500	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1979
TRIHALOMETHANES	LE	0.35	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1979
TRITIUM	LE	40 000	Bq/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1979
TURBIDITY	LE	5	NTU	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1979
URANIUM, as U	LE	20	µg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1979
ZINC, as Zn	LE	5.0	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1979

GE – Greater than or equal to.
LE – Less than or equal to.
LT – Less than.
mg/L – Milligram per litre.
No./dL – Number per decilitre (100 mL).
Bq/L – Becquerel per litre.
TCU – True Colour Unit.
µg/L – Microgram per litre.
NTU – Nephelometric Turbidity Unit.
ND – Non detectable.

Source: McNeely *et al.* (1979).

Appendix B
Water Quality Analysis Report

APPENDIX B

WATER QUALITY ANALYSIS REPORT

The following water quality analyses (Table B-1) are examples of a more complete report, including dissolved metals and tests for chemical and bacteriological contamination, as required, where ground waters are to be used for municipal water supplies.

The samples, 2 L each, were collected in January 1982 from Elk Creek Pump Station, Well No. 50, and CFB Chilliwack, Well No. 51 (Table C-1, Appendix C). The samples were analyzed by CanTest Ltd., Vancouver.

Table B-1. Water Quality Analysis Report

Chemical properties	Well No. 50	Well No. 51
pH	7.70	7.85
Conductivity (μS/cm)	104	102
Colour(TCU)	5	5
Turbidity (NTU)	0.17	0.20
Hardness (mg/L $CaCO_3$)	47.0	43.5
Alkalinity: bicarbonate, HCO_3	52.0	48.0
Alkalinity: carbonate, CO_3	Nil	Nil
Solids (mg/L)		
Total suspended	0.5	0.5
Total dissolved	95	90
Fixed dissolved	50	35
Volatile dissolved	45	55
Dissolved anions (mg/L)		
Chloride, Cl	2.50	2.00
Sulphate, SO_4	8.0	6.0
Nitrates, N	0.050	0.13
Nitrites, N	0.002	0.002
Orthophosphates, o-PO_4	1.99	0.86
Fluorides, F	0.076	0.11
Dissolved cations (mg/L)		
Calcium, Ca	16.5	15.3
Magnesium, Mg	1.39	1.29
Manganese, Mn	0.003	0.003
Iron, Fe	0.030	0.030
Sodium, Na	1.74	1.74
Potassium, K	0.66	0.58
Silicon, SiO_2	9.11	7.82
Contaminant test (mg/L)		
Ammonia nitrogen, N	0.05	0.05
Total Kjeldahl nitrogen, N	0.10	0.10
Surfactants (MBAS)	0.10	0.10
Total organic carbon, C	3	2
Dissolved metals (mg/L)		
Antimony, Sb	0.001	0.001
Arsenic, As	0.001	0.001
Barium, Ba	0.011	0.011
Boron, B	0.030	0.023
Cadmium, Cd	0.001	0.001
Copper, Cu	0.015	0.015
Lead, Pb	0.001	0.001
Mercury, Hg	0.000 10	0.000 15
Selenium, Se	0.001	0.001
Silver, Ag	0.001	0.001
Zinc, Zn	0.015	0.015
Uranium, U (μg/L)	0.20	0.25

TCU – True Colour Unit.
NTU – Nephelometric Turbidity Unit.

Appendix C
Yields of Significant Wells

APPENDIX C

YIELDS OF SIGNIFICANT WELLS

All the wells recorded in the 1915 inventory were drilled by the jetting method, and all were 50 to 75 mm in diameter and flowing artesian. The installation of wells by the jetting method (Fig. 38) continued to be commonplace until the late 1940s. The success of this method was limited to those areas within the discharge zones of regional flow systems, primarily the Nicomekl, Serpentine and Hazelmere valleys. As agricultural development expanded in the upland areas, cable-tool drilling was found to be a favourable method of installing successful wells in the unconsolidated deposits where well diameters had to be sufficient (150 mm) to accommodate deep well pumps, and depths commonly were less than 60 m. Rotary drilling was used mainly in those areas north of the Fraser River where ground water is developed from bedrock. Today, drilling is carried out in the Fraser Lowland by sophisticated equipment combining rotary and reverse circulation methods, and well diameters range from 150 to 610 mm, depending on the anticipated yield.

Early in the 1950s, with the introduction of well screens, aquifer development became an important part of well drilling. A well screen (Fig. 39) is fabricated to provide a continuous slot-type opening that permits water to flow freely into the well from the saturated unconsoli-

Figure 38. Drilling wells by jetting, 1955.

Figure 39. Well screen.

Figure 40. Set-up for a pump test.

dated aquifer materials. The length of the screen is determined by the thickness of the aquifer, and the correct slot size is determined by sieve analysis of samples obtained during drilling. Screen installation is followed by a development process to bring the well to its maximum capacity, and thereafter a pump test can be carried out to determine the aquifer potential and the safe yield of the well. A pump test (Fig. 40) may involve the production well only or, where a more complete aquifer test is required, a number of auxiliary wells are installed to provide additional observation points from which to measure water levels.

Essentially a pump test is the pumping of a well at a constant rate and the observation of the water level in the well during pumping. The level at which the water stands in the well when no water is being taken from the aquifer is the static water level. Those static water levels reported in Table C-1 were measured upon well completion or at the beginning of a pump test and are now not necessarily equal to the static level, owing to seasonal variations related to recharge and discharge within the aquifer system. The level at which the water stands in the well when pumping is in progress is the pumping level. Drawdown is the difference measured between the static and pumping levels, and the specific capacity is calculated by dividing the volume of water discharged per unit of time by the drawdown measured in metres at the same time. The specific capacity, which is an expression of the productivity of the well, is expressed as litres per second per metre of drawdown. A more realistic measure of the capacity is achieved when wells are rated by taking into account the total available drawdown and the well efficiency.

When a well begins to pump, water within the aquifer moves radially toward the well, and as the pumping level lowers, a conical dip develops in the water table (Fig. 41).

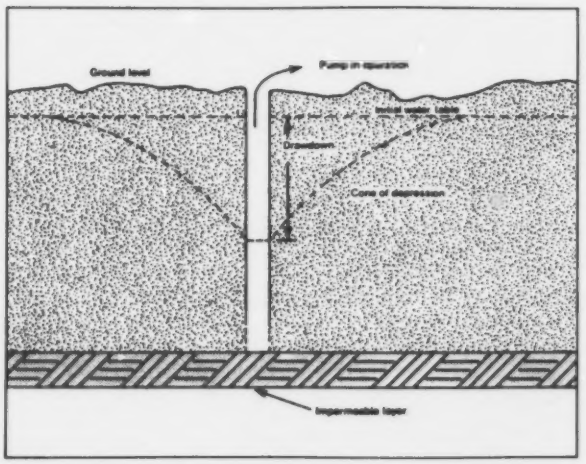

Figure 41. Typical cross section of a well being pumped.

Table C-1. Design and Statistics, Production Wells

Municipality or district	Location No. (Fig. 42)	Depth (m)	Diameter (mm)	Static water level (m)	Screen assembly: Diameter (mm)	Screen assembly: Slot size (mm)	Screen assembly: Interval (m)	Duration of pump test (min)	Average rate of pumping (L/s)	Specific capacity of drawdown (L/s)	Average transmissivity (m/s)	Rate (L/s)	Present status*	Source of data and remarks	Year
Delta	1	75	254	53.3	203	0.38 0.25 1.27	69.9–71.4 71.4–73.5 73.5–75	120	12.5	1.2			N		1955
Delta	1	64.6	254	44	203	0.63 0.38 0.25	56.4–59.5 59.5–61.6 61.6–64.6	120	11.3	0.9			N	Pacific Water Wells (1969) Ltd. Three wells delivered 47.3 L/s to a 3785 m³ reservoir	1955
Delta	1	73.4	254	55.4	203	1.00	69.4–73.4	160	26.5	2.4			N		1955
Surrey	2	32.3	305	22.2	254	2.54	31–33.2	300	15	4	0.079	15	I	Pacific Hydrology Consultants	1962
Surrey	2	48	203	27.6	203	2.54 0.50 0.33	34.5–35.6 35.6–38.9 46.5–48.0	1250	9.4	1.8	0.003	9.5	I	Green Timbers Forest Nursery	1972
Surrey	2	35	203	21.6	203	0.63 0.63	29.0–30.6 32.6–34.0	600	15.7	2.7	0.005	15	I	Annual requirement 10 000 m³	1980
Surrey	3	149	203	102	203		121–149	4320	25	7.3	0.002	25	ST		
Surrey	3	151	406	105	254			1092	50		0.012	250	ST	Ker, Priestman & Assoc. Ltd.	1976
Surrey	4	123.4	203	97.8	203	1.52 3.17	117–123.4			24.8		38	N	Brown, Erdman & Assoc. Ltd.	1959
Surrey	4	117.3	305	97.8					27.5	4.5		26.2	N	Surrey Municipal Wells	1963
Surrey	4	124	406	99.7	305	3.8	113–124	1440	69	13.6	0.043	75.6	ST	McBeth Rd.	1966
Surrey	5	104.7	203	80.7	203	1.27 2.54 3.17	101.5–101.8 101.8–102.4 102.4–104.7	420	26.8	32.8		28	M	Robinson & Roberts Ground Water Consultants	1959
Surrey	5	97.5	203	74.9	203	5.08	94.3–97.5	1320	26.5	10.3	0.020	30	M	Dayton & Knight Ltd.	1972
Surrey	5	103.3	508	81.6	406	0.38 0.50 0.38 0.30	94.5–96.3 96.3–100.0 100.0–101.2 101.2–103.3	1000	37.8	11.8		28	M	White Rock Utilities Pacific Water Wells (1969) Ltd.	1974

* D – Domestic, I – Irrigation, Id – Industrial, M – Municipal, N – Not used, O – Observation, S – Subdivision, ST – Standby, f.a. – Flowing artesian.

Table C-1. Continued

Municipality or district	Location No. (Fig. 42)	Depth (m)	Diameter (mm)	Static water level (m)	Screen assembly: Diameter (mm)	Screen assembly: Slot size (mm)	Screen assembly: Interval (m)	Duration of pump test (min)	Average rate of pumping (L/s)	Specific capacity of drawdown (L/s)	Average transmissivity (m/s)	Rate (L/s)	Present status	Source of data and remarks	Year
Surrey	5	101.8	508	82.3	406	2.54 0.48 3.80	91.4–101.8	1000	60.7	14.6	0.018	63	M	Aqua-flo Testing & Equipment Ltd.	1981
Surrey	6	22	203	2.4	203	1.00	18.2–22	600	17.6	14.4		5	N	Crescent Beach Water Works, Engineering Dept., Surrey District Municipality	1956
Surrey	7	136	305	0	203	0.76	126–136					6.5	N	Also a well 87 m deep. Engineering Dept., Surrey District Municipality	1964
Surrey	8	58.3	203	48.4	203		55.3–58.3					3.8	N	Surrey Municipality Well Dayton & Knight Ltd.	1962
Surrey	9	90	254	43	203	0.63	86.3–90					3.8	N	Cloverdale No. 1 well Brown, Erdman & Assoc. Ltd.	1958
Langley	10	133	305	f.a.	203	2.54 0.76	120.7–122.0 131.2–132.4	2880	38	0.76	0.001	38	M	Fort Langley Well Field	1976
Langley	10	20.3	406	1.5	406	6.35	17–20.3	1830	151	103.0	0.017	150	M	Brown, Erdman & Assoc. Ltd.	1976
Langley	11	18.2	203	11.7	154	1.52 0.58	14.7–16.2 16.7–18.2			15.4		14	N	Copper Beach Water System Brown, Erdman & Assoc. Ltd.	1975
Langley	12	137	305	24.5	305	1.27	115.8–120.4	17 280	25	0.37	0.007	25	M	Willoughby Production Well No. 1, Brown, Erdman & Assoc. Ltd.	1978
Surrey	13	28	203	5.4	203	1.00 0.50 0.30 0.38	18.5–20.0 20.0–23.0 25.0–26.5 26.5–28	540		25	0.002	20	I		
Surrey	13	28.4	203	5.5	203	0.25 0.30 0.25	21.0–24 24.0–25.5 25.5–27.0	600	14.3		0.045	38	I	B.C. Forestry Nursery	1980
Surrey	13	43.9	203	4.3	203	0.25 0.38 0.30 0.45 0.50	33.3–34.8 34.8–36.3 36.3–39.3 39.3–40.8 40.8–42.3	320	46.2	22	0.038	38	I	Pacific Hydrology Consultants	1980

Table C-1. Continued

Municipality or district	Location No. (Fig. 42)	Depth (m)	Diameter (mm)	Static water level (m)	Screen assembly: Diameter (mm)	Screen assembly: Slot size (mm)	Screen assembly: Interval (m)	Duration of pump test (min)	Average rate of pumping (L/s)	Specific capacity of drawdown (L/s)	Average transmissivity (m/s)	Rate (L/s)	Present status	Source of data and remarks	Year
Langley	14	20	203	2	203	0.50 0.88	12.4–18.5 18.5–20.0	1440		2.5	0.036	38	M	Sully Well No. 2 Robertson & Roberts	1960
Langley	15	23.7	203	2	203	0.50	20.2–23.7			1.0	0.007	10	M	Langley Municipal Production Well No. 5	1971
Langley	16	23.3	305		203	1.52 2.00 1.00	16.0–17.6 17.6–20.0 20.0–23.0			3.2		17	M	Langley Municipal Production Well No. 1, Brown, Erdman & Assoc. Ltd.	1960
Langley	16	22.0	305		203	1.00	15.5–22.0			2.7		15	M	Langley Municipality Production Well No. 2	1960
Langley	16	29	203	6	203	0.50	26.0–29.0						M	Langley Municipality Production Well No. 6	1971
Langley	16	27	305		305	0.25	18.5–24.6			2.0	0.004	16	M	Langley Municipality Production Well No. 4	1973
Langley	17	35.4	406	4.5	254	0.76	29–35.2	5750	35.7	2.5	0.004	30	M	Langley Municipality Production Well No. 8, Brown, Erdman & Assoc. Ltd.	1979
Langley	18	57.9	254	5.3	254	2.54 0.76 1.52	46.6–48.1 50.2–51.7 51.7–57.9	2470	38.8	1.1	0.002	30	M	Langley Municipality Production Well No. 7, Pacific Hydrology Consultants	1974
Langley	19	115.5	203	26.6	203	1.27 1.27	98.9–105.4 112–115.5	210 4750	29.8 25.2		0.003	15	M	Murrayville Test Well No. 1 Brown, Erdman & Assoc. Ltd.	1978
Langley	19	63	305	f.a.	254	1.27	51.6–63	4320 7200	105 38		0.003	75	M	Murrayville Well, Old Yale Rd. Brown, Erdman & Assoc. Ltd.	1979
Langley	20	66.7	203	f.a.	203	0.38 0.76 1.00	59.3–60.8 60.8–62.3 62.3–65.4	325	12.6	0.2	0.000 15	9	I	Murray's Nursery Pacific Hydrology Consultants	1975
Langley	21	37.3	203	2.7	152	0.76	30.0–37.3	8620	3.8	0.7	0.002	8.5	S	Forest Knotts Subdivision Brown, Erdman & Assoc. Ltd.	1973
Langley	22	68.2	305	22	254	5.08	62.0–68.2	1440		2.0	0.058	125	I	Pacific Hydrology Consultants	1978

Table C-1. Continued

Municipality or district	Location No. (Fig. 42)	Depth (m)	Diameter (mm)	Static water level (m)	Screen assembly: Diameter (mm)	Screen assembly: Slot size (mm)	Screen assembly: Interval (m)	Duration of pump test (min)	Average rate of pumping (L/s)	Specific capacity of drawdown (L/s)	Average transmissivity (m/s)	Rate (L/s)	Present status	Source of data and remarks	Year
Langley	23	48	203	23.4	203	0.63 0.50	42.3–48	720	3.8	1.4		3.8	S	Larco Subdivisions Pacific Water Wells (1969) Ltd.	1973
Langley	24	71.3	203		203	1.27 1.52	66.7–68 68–71			0.96	0.003		S	Tall Timbers Subdivision	1979
Langley	25	168	203	46	152	0.30 0.25 0.17	158.5–162.9 162.9–164.4 164.4–165	1000	10	0.15	0.000 2	10	S	Ben Pel Subdivision Brown, Erdman & Assoc. Ltd.	1979
Langley	26	51	152	29.7	152	0.76	46–51	1450	6.5	17	0.019	19	D	Otter Shopping Mall Brown, Erdman & Assoc. Ltd.	1979
Maple Ridge	27	36.5	152	1.2	152	1.00	33.8–36.5	480	7	1.2	0.003	12.6	O	B.C. Ministry of the Environment	1981
Langley	28	109	152	56.3	152	0.76	107–109	1500	6.3	0.37	0.002	7.5	I	Geol. Survey of Canada, Bull. 64–51	1963
Langley	28	27	203	8.3	203	0.50	23.6–6–27	3000	2.3	0.2	0.000 3	2.3	D	C.F.B. Aldergrove	1974
Langley	28	38	203	10.8	152	0.38	32.5–37.8	1500	1.9	0.14		1.9	D	Brown, Erdman & Assoc. Ltd.	1975
Langley	29	35	203	12	203	0.63 0.25	30.2–34.3	1400	4.4	14.5			M	Aldergrove Production Well No. 1, Boundary Ave.	1962
Langley	29	38	203	10.9	203	1.00 0.76	31.9–9.38	1440	18.9	2.9			M	Aldergrove Production Well No. 2, Boundary Ave. Brown, Erdman & Assoc. Ltd.	1972
Langley	30	33.2	305	6	254	1.27	28.5–33.2	7100	48.5	2.75	0.005	44	M	Aldergrove Production Well 272 St. and 25 Ave.	1977
Matsqui	31	28.2	203	15	203	0.50	25.3–28.2	900	11.3	2.4		8	M	Dayton & Knight Ltd.	1961
Matsqui	32	32		24		0.76	29–32	60	5.6			9	M	Bradnew Well, Dayton & Knight Ltd.	1970
Matsqui	33	9	304	1.8	254		7.2–9	150	4.4	1.4		10	M	Mt. Lehman Rd. Well	1962
Matsqui	34	44.5	304	24	304	3.04 3.04 5.08	33.2–35.6 39.9–41.7 42.9–44.5	300	53	4	0.003 4	50	I	Valley Gravel Sales Pacific Hydrology Consultants	1977

Table C-1. Continued

Municipality or district	Location No. (Fig. 42)	Depth (m)	Diameter (mm)	Static water level (m)	Screen assembly: Diameter (mm)	Screen assembly: Slot size (mm)	Screen assembly: Interval (m)	Duration of pump test (min)	Average rate of pumping (L/s)	Specific capacity of drawdown (L/s)	Average transmissivity (m/s)	Rate (L/s)	Present status	Source of data and remarks	Year
Matsqui	35	12	304	3		1.00	7.6–12	960	12.6			12	I	Clearbrook Food Processing Plant	1959
Matsqui	35	18	304	2		1.00 1.52 1.00	12–18		41	9.8			I	Clearbrook Food Processing Plant	1967
Matsqui	36	26.7	457	5.6		3.8 1.00 0.50	21.7–26.7	4260	82	12.5			M	Matsqui Municipal Townline Rd. Wells	1975
Matsqui	36	18.6	254	3.4		3.8	15.0–18.6	3000	62	8.2		25	M	Dayton & Knight Ltd.	1978
Matsqui	37	35.8	304	18	304	1.00	29–35.8		19	20			M	Marshall Rd. Well No. 2	1958
Matsqui	37	37.6	355	19	355	2.03	33.6–37.6	4320	63	5.7			M	Marshall Rd. Well No. 5 Dayton & Knight Ltd.	1967
Matsqui	37	42.5	610	18	457		33.6–42.5					125	M	Marshall Rd. Well No. 3	1971
Matsqui	38	31.4	254	13	203		28.6–31.4	1080	22	7		3.8	M	Clearbrook Water Works Well No. 1	1954
Matsqui	38	37	254	14.5	254	1.52 2.54	34–35.6 35.6–37	60	25	7		29.5	M	Clearbrook W.W. Autumn Rd. Well	1963
Matsqui	38	83.7	203	42	203	1.52 2.03	75.8–78.9 82.2–83.7	245	3.8	0.6		3.8	M	Clearbrook W.W. at tower	1980
Matsqui	39	35	203	8.2	203	0.76	30–35	400	30	6.5		40	I	Valley Rite Mix, Pacific Water Wells (1969) Ltd.	1982
Matsqui	40	8.5	254	1.3	254	1.27 2.03	6.9–8.5	150	19	60		18	M	Hazelwood Well Dayton & Knight Ltd.	1958
Abbotsford	41	18.5	203	1.5	203	0.76 1.00	13.7–18.5		14.5	1.7		13.5	M	Well No. 1, Essendene Street	1954
Abbotsford	41	22.2	304			2.03	17.6–22.2		33			20	M	Well No. 2, Pine Street Dayton & Knight Ltd.	1960
Abbotsford	42	32	304	16	304	1.52 2.03	27.4–32		25	3.5		22	M	Well No. 3, McCallum Rd. & Freeway	1966

Table C-1. Continued

Municipality or district	Location No. (Fig. 42)	Depth (m)	Diameter (mm)	Static water level (m)	Screen assembly: Diameter (mm)	Screen assembly: Slot size (mm)	Screen assembly: Interval (m)	Duration of pump test (min)	Average rate of pumping (L/s)	Specific capacity of drawdown (L/s)	Average transmissivity (m/s)	Rate (L/s)	Present status	Source of data and remarks	Year
Abbotsford	43	24.3	203	14.5	203	0.76	21.8–24.3	300	9	1.5		6	M	Brown, Erdman & Assoc. Ltd.	1963
Abbotsford	44	16	304	3.8	304	0.76	11.5–16	3240	27	3.8	0.011 1	14	M	Ker-Priestman & Assoc. Ltd. Riverside No. 2	1972
Abbotsford	45	44	457	4	355	3.17 2.54	34.3–40.4 40.4–44	2920	114	4.4	0.086	90	M	Farmer Rd. Well No. 1 Ker-Priestman & Assoc. Ltd.	1973
Abbotsford	45	47	457	6.2	355	0.76 2.54 0.50	34.2–41 41–45.6 45.6–47	7200	124	7	0.716	114	M	Farmer Rd. Well No. 2 Ker-Priestman & Assoc. Ltd.	1977
Abbotsford	46	80.7	457	11	457 304	2.54 2.54	36.2–39.3 39.3–80.7	480	153	16	0.026		I	Abbotsford Trout Hatchery B.C. Ministry of the Environment	1980
Mission	47	48.7	203	1.5	203	2.54 3.80	43.8–45.4 45.4–48.7		30	1.7			N	A&H Construction Co. Ltd.	1976
Nicomen	48	21	508	3	406	3.80	13.6–21	5770	96	98.4	0.273	95	I	Inches Creek Production Well No.1, Fisheries & Oceans Canada	1977
Nicomen	48	21.5	508	3.9	406	3.80 2.54	13.3–17.0 17.0–21.5	2480	140	41	0.156	95	I	Inches Creek Production Well No.2, Fisheries & Oceans Canada	1978
Nicomen	49	48	203	f.a.	203	0.38	43–48	4320	12.5	1.0	0.001 4	15	D	Trailer Park, Brown, Erdman & Assoc. Ltd.	1981
Chilliwack	50	24.6	203	7.8	203	2.03	20.5–24.6	560	50	41.3		13	M	Elk Creek Water Works	1973
Chilliwack	50	30	406	8.3		3.89 4.57 5.58	18.2–20.7 24.3–25.4 27.4–29.8	240	126	62.3		20	M	Pacific Hydrology Consultants	1977
Chilliwack	51	34	406	18	304	6.20	28–34	1520	75	34.4	0.043	68	D	Canadian Forces Base Chilliwack	1964
Chilliwack	51	45	406	16	304	3.8	38.6–45	1500	75	6	0.020	68	D	Brown, Erdman & Assoc. Ltd.	1975
Chilliwack	52	70	203	f.a.	150	0.76 1.52	67–68.5 68.5–70.0			62.3		20	I	Slesse Creek Production Wells	1970

Table C-1. Continued

Municipality or district	Location No. (Fig. 42)	Depth (m)	Diameter (mm)	Static water level (m)	Screen assembly			Duration of pump test (min)	Average rate of pumping (L/s)	Specific capacity of drawdown (L/s)	Average transmissivity (m/s)	Rate (L/s)	Present status	Source of data and remarks	Year
					Diameter (mm)	Slot size (mm)	Interval (m)								
Chilliwack	52	118	406	f.a.	304	2.03 0.76 0.50 0.76 1.52	101–103.6 103.6–108.5 108.5–114.9 114.9–116.4 116.4–119	9800	107	370		300	I	Fisheries & Oceans Canada Pacific Hydrology Consultants	1978
Kent	53	29.0	406	1.12	304	6.2	17.5–26.9		138	18.8	0.08	183	I	Chehalis Fish Hatchery	1980
Kent	53	27.2	406	2.13	304	6.2	17.7–27.2		75	9.3	0.04	98	I	Fisheries & Oceans Canada Piteau & Associates Ltd.	1980
Kent	53	23.4	406	1.27	304	6.2 3.7	12.79–17.56 17.36–23.4		40	10.2		65	I	See Figure 23 for well locations	1980

The radius of this cone of depression depends upon the hydraulic characteristics of the aquifer, and its expression is defined only in those pump tests where auxiliary observation wells have been installed in proximity to the pumping well. During the early stages of the pump test the water level changes rapidly, and it is essential that water level measurements are taken at brief intervals as pumping continues. Recording the rate of recovery of the water level in the well after the pump has been turned off is equally important. The water level readings are plotted as time-drawdown graphs on log-log and semi-log charts from which transmissivity values are calculated using the straight-line method of Cooper and Jacob or the type curve method of Theis (Freeze and Cherry, 1979). The aquifer transmissivity is an expression of the ease with which the aquifer materials permit the movement of water through it; and it is the product of the hydraulic conductivity and aquifer thickness, expressed as the rate in square metres per second, at which water at prevailing density and viscosity is transmitted through a unit of the aquifer under a unit hydraulic head.

Table C-1 lists a number of production wells that have been designed and installed for municipal, irrigation and industrial purposes. Location of the wells is shown in Figure 42 (in pocket). The table indicates the well design and screen assembly, followed by a description of the pump test and results as evaluated by the various agencies responsible for the well development. Many of the pump tests were performed on single wells with no observation well support, and the tests were carried out at predetermined rates until such times as the pumping level was reasonably stable. In such cases, transmissivity values are not available, and the specific capacities may not be reliable, although some wells have been pumped for long periods of time. Transmissivities are recorded where pump tests were carried out for sufficient time and, in most cases, supported by observation well measurements. Transmissivity values may have considerable variance depending on the analytical method used for evaluation, and sometimes recovery data were also processed to provide a value range. The transmissivity values presented in the table are in most cases an average of those available and ranged from 0.000 15 m^2/s to 0.273 m^2/s. Freeze and Cherry (1979) suggest that a transmissivity value greater than 0.015 m^2/s represents a good aquifer for well exploration, and within the Fraser Lowland values in this range commonly occur in water table aquifers represented at or near the surface as deltaic, outwash and fan deposits (hydrostratigraphic unit C). In some areas, as at Green Timbers Nursery, Surrey District Municipality, and also the production wells for Whiterock Water Works, confined aquifers within till and multi-till (hydrostratigraphic unit D) sequences provide like volumes of ground water. It is also significant that transmissivity values, like many useful mathematical relationships, are an approximation of reality and should be used understanding these limitations. For example, a well at Ben Pel Subdivision (Table C-1, Well No. 25) has a low calculated transmissivity of 0.0002 m^2/s, but is capable of providing more than 2.35×10^4 m^3 annually.

The rated capacity or safe yield reported is that suggested by the consulting agency, taking into consideration the total available drawdown, the efficiency of the well and the total life expectancy or operation of the well.

MAPS NOT

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CARTES

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